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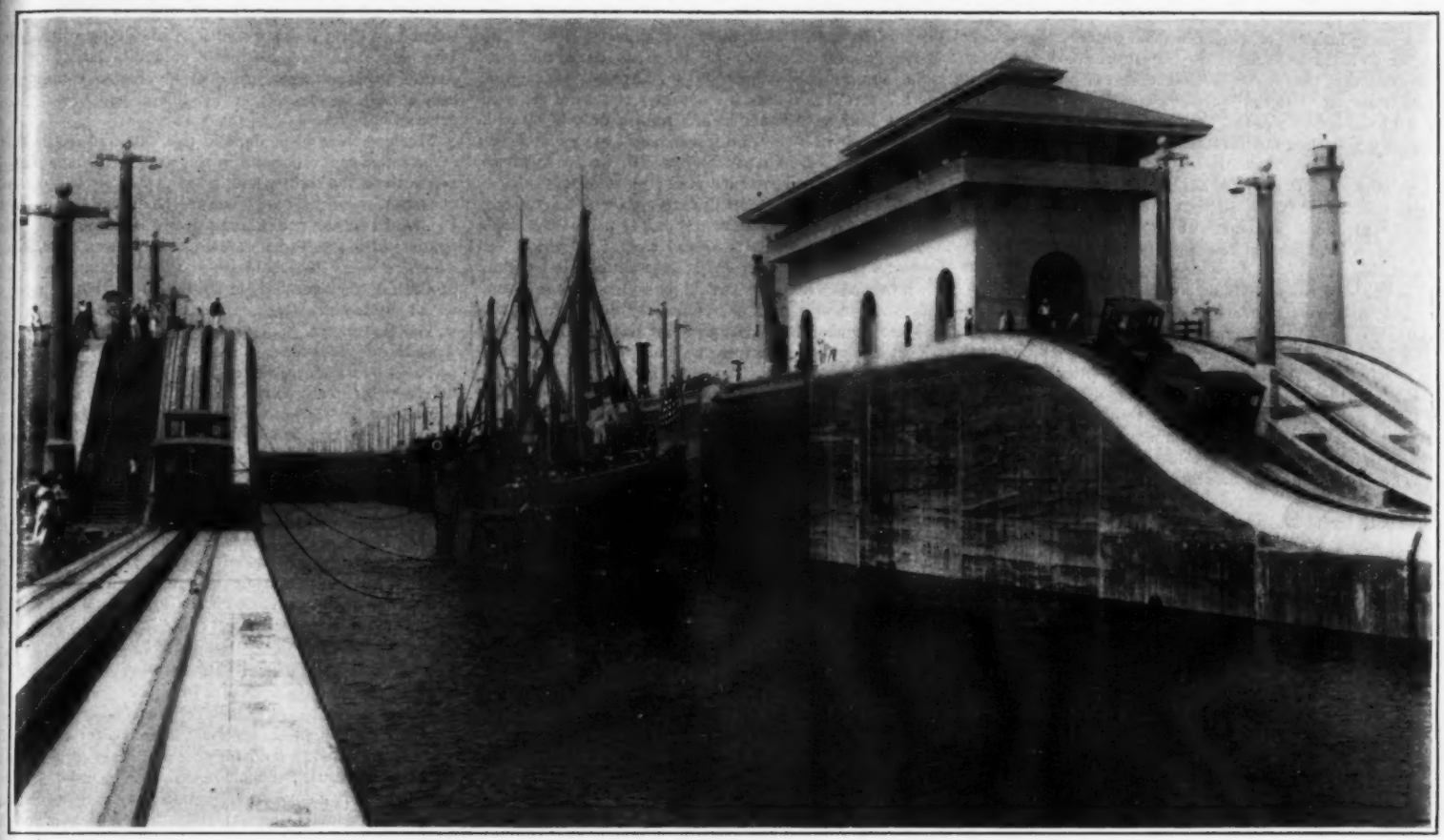
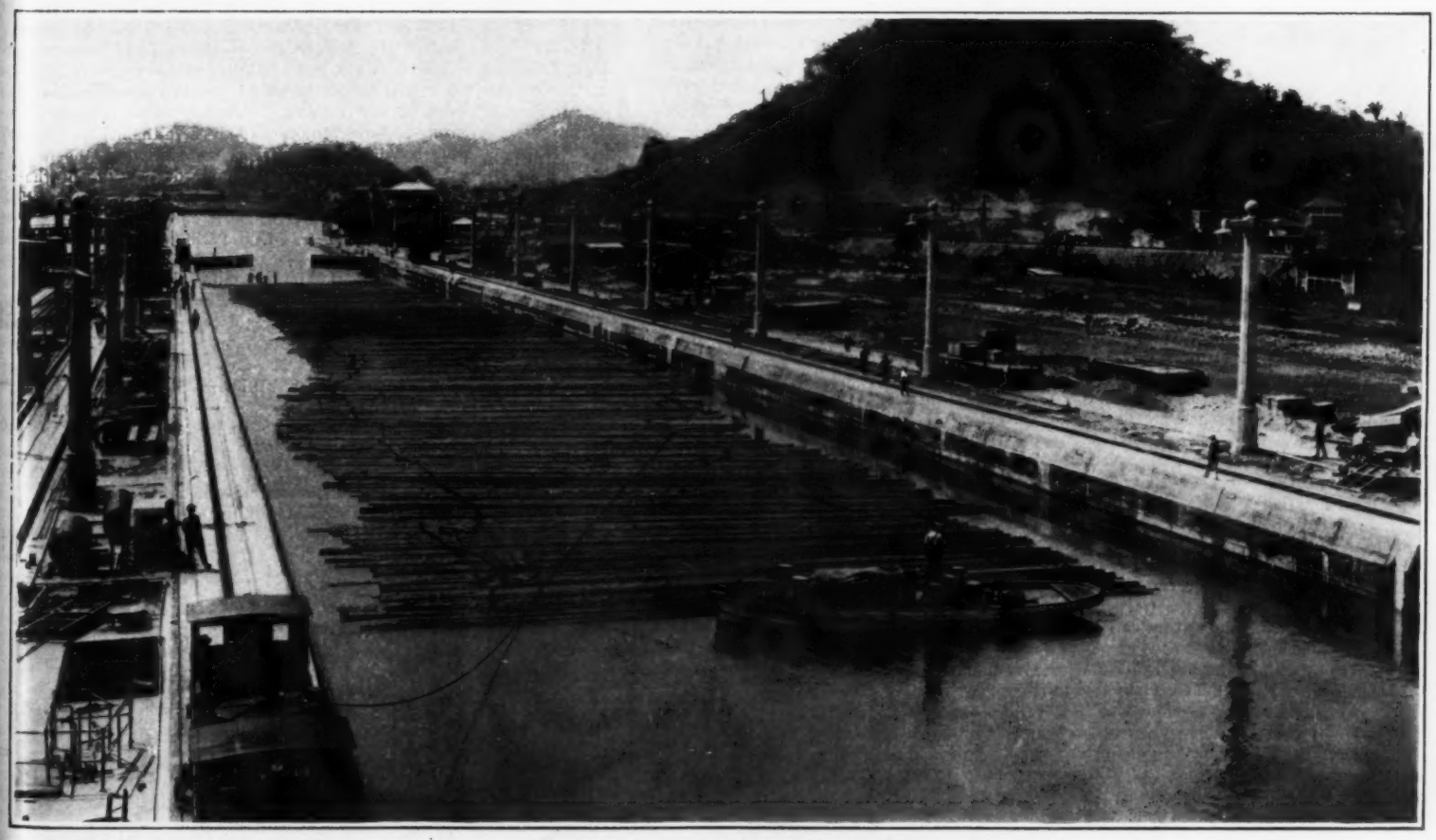


Tender "Severn" leaving Gatun lock in tow of electric locomotives.



A raft of piles from Balboa in the Pedro Miguel locks.

TOWING VESSELS THROUGH THE PANAMA CANAL LOCKS BY ELECTRIC POWER.—[See page 72.]

Plancton, the Ultimate Food

Vast Resources of the Ocean from Which the Fish Obtain Their Sustenance

ONE of the most brilliant achievements of modern biology is the demonstration of the vast variety, bulk, and importance of the living creatures, both animal and vegetable, which swarm thickly in the clearest sea-water, and are known collectively by the name of plancton. Since the ocean covers two-thirds of the surface of the globe, and since these aquatic forms of life exist throughout many fathoms of depths, instead of merely in a thin layer of earth and air as do terrestrial creatures, it is obvious that they are enormously superior in numbers and in actual "tonnage."

But the very tiniest of these, the low vegetable forms which derive their nutriment directly from the water and its inorganic constitutents, themselves become the food for slightly higher forms of animal life, and these in turn feed still higher forms, so that the humbler marine life is the ultimate provender of those food-fishes which supply so large and increasing a portion of the food of mankind.

Millions of the planctonic creatures are either microscopic in size or so transparent as to be invisible ordinarily. However a pretty experiment demonstrates the presence of some of these tiny forms. It consists in placing a glass dish full of clear sea-water in a dark room and then allowing a beam of light to fall upon it. Just as such a beam will show the motes dancing in air it will show thousands of shining particles which are really living beings dancing in the water.

The planctonic creatures are divided into two great classes, those which are pelagic, i. e., the ones whose whole life, both larval and adult, is spent floating in water, and those which are attached to the submarine soil during part of their existence. The latter are found especially in littoral waters. Marine plancton, which is of course far more important than the fresh water plancton, though this also exists in great quantities, is also divided into the oceanic, found in the deep seas, and the neritic, which is found near shore, that is, above the continental plateau.

Some good work has been done in this country in the study of plancton, especially on the coast of California, but the great authority on the subject is the well-known scientist Dr. Richard of the Marine Museum of Monaco. We are indebted for the facts in this article chiefly to the researches of Dr. Richard as reported in a recent encyclopedic article in *Larousse Mensuel*. The first method of collecting plancton for study was by a net much resembling an ordinary butterfly net attached to a line instead of to a pole and trailed behind a boat. But the resistance of water is so much greater than that of air that the fine silk gauze or bolting-cloth used for the net interfered with the filtering of the water at even a moderate rate of speed. Hence Dr Richard modified the shape of the net by making its length greater and its orifice smaller This increases the surface of filtration and the plancton collects in the end of the long cigar-shaped net and is examined at leisure in the laboratory.

A very important point is to test the amount of plancton in a given quantity of water. This is accomplished by emptying the plancton into a graduated beaker. At the end of several hours it has collected in the bottom of the beaker and its bulk is indicated by the figure at which it stands. Thus an estimate is readily formed of the comparative alimentary richness of any given area of the sea, information of great practical value in the fisheries industries. But it is likewise highly important to know the nature and habits of the species found, since some of these form the favorite food of sardines, lobsters, crabs, cod, herring, or other of the chief food fishes, and a knowledge of their habits and their habitats is immensely useful to the fisherman who would make a full haul.

Such examination of species is chiefly conducted in the laboratory, but preliminary work can be done on board ship by an apparatus invented by Dr. Richard, which consists of a glass dish filled with the water to be examined, a lense, a mirror inclined at an angle of 45 degrees, and a white screen on which the images of the tiny creatures are thrown; the apparatus is completed by a device which compensates the rolling of the vessel.

It is very beautiful to see how exquisitely the creatures which compose the plancton are adapted to their peculiar mode of existence. The most striking feature of this adaptation is the crystalline transparence of most of them which makes it difficult to distinguish them from the water which surrounds them. "It is very curious to see muscles, cartilages, and teguments which resemble glass without being altered in their functions; they can scarce be distinguished from the water except by mingling therewith some reagent which kills them and coagulates and renders opaque their tissues." A similar modification is the clear blue tint of many of the pelagic creatures which live near the surface. This is a very characteristic case of protective coloring, and is never found in specimens found at great depths where the sun does not penetrate.

Since the tissues of these animals are infiltrated with water they have a density approximately that of the water by which they are surrounded; but since even their very slight excess of density would carry them down sooner or later they are provided with special compensating apparatus. Sometimes they have fins whose force can be exerted in a direccion contrary to that of gravity; or they may have floats consisting of a drop of oil or a bubble of air in a contractile sac. Still others have appendages shaped like paddles, or like feathers, whose surface resists the downward pull.

"All these creatures, to diminish their density, have eliminated from the organism the heavy parts—the thick bones, compact shells, resistant carapaces which are borne by their congeners of the littoral and the bottom. Thus one observes very curious creatures among them, whose viscera occupy a comparatively small part of the gelatinous mass of their transparent bodies."

Very often the planctonic animals which live several hundred meters below the surface have developed enormous eyes; their antennae and their claws are elongated also, and the minute organs of sensation which cover their bodies are hypertrophied. The pelagic animals which live at great depths develop "telescopic" eyes, i. e, they are cylindrical instead of globular. This is only found at such depths that only the ultra-violet rays of the solar spectrum can penetrate. Another notable feature is that the otocyst, the organ which replaces the ear in inferior animals, is highly developed and acts as an organ of equilibrium.

Their fecundity is, of course, enormous and the ship "National" on one occasion observed a great swarm or shoal of one variety floating on the surface and no less than 260 kilometers long. Obviously such a huge mass of tempting food material will attract hungry schools of fish, hence it is of interest to learn what conditions the presence or absence of various kinds of plancton in any given locality. It has already been observed that the composition of the plancton in any place varies at different seasons or even different times of the day. Thus they will descend when the surface of the ocean is agitated for their bodies are too delicate to bear violent motion. Rain also drives them down, since they are not fitted for contact with fresh water. Some cannot bear light and fly from the approach of daylight, while others execute the inverse movement Hence the "catch" of plancton varies according to whether the net is cast by day or by night. Some varieties appear only at certain seasons of the year, which fact may be due to variations in the temperature of the superficial layers of the water; and still others appear only at intervals of several years, for reasons as yet unknown. Such facts as these are of prime importance to the fisherman, and it is hoped that when these movements of plancton are fully understood much of the present uncertainty in the fisheries industry may be eliminated.

Most of the plantonic plants are microscopic algae, a large percentage being composed of immense shoals of diatoms. These are most abundant in the cold waters of the temperate and the polar seas. It has been estimated that a cubic meter of water off the coast of Iceland contains 5 billions of them Another common species is the peridinians, which are ranked as plants because of the carapace of cellulose, though some of their characteristics relate them to the protozoa.

Among the pelagic protozoa special mention is due to the *foraminifera*. These secrete a tiny shell of calcareous matter, through whose apertures extend the long filament of the animal's gelatinous body. When the animal dies this shell is no longer buoyed up and slowly sinks. More than 150 million square kilometers of the bottom of the sea are thickly carpeted with a mass of these tiny shells. Nearly two-thirds of the bottom of the Atlantic is covered with them. A curious fact is that they are not found below 5,000 meters in depth, because their substance being slightly soluble in water is dissolved by the time it has reached a certain depth It is of such deposits as these that our sedimentary rocks are made. Similar deposits are made by the species radiolaria, but as their skeleton is silicious it is less soluble and is therefore found in very deep areas of the Pacific ocean. The common phenomenon of phosphorescence in salt water is due to other species, and persons who take sea-baths at night often observe shining flecks like scraps of phosphorus clinging to their garments.

Other varieties are the *coelentera* and the *siphonophores*. Also the larvae of the *echinoderms* and of eels. Besides these may be mentioned certain molluses. *Crustacea*, too, are abundant both in fresh-water and salt-water plancton. "Their small species, especially the *copepods*, swim in huge shoals. They are found in all seas and form the basis of the animal nutriment of marine animals; it is these above all on which the sardine feeds and the movements of shoals of sardines follow those of *copepods* and *peridinians*. Doubtless the presence of the latter is dependent on varying conditions of temperature, salinity, etc., and the apparently recondite labors of the marine geologist may prove of invaluable commercial aid, another argument for the liberal support of pure science.

Much remains to be done in this vast and fertile field of investigation, especially in the study of pelagic plancton both on the surface and in the depths of the sea. In closing, a word must be given to the special net devised by Dr. Richard for obtaining deep sea plancton. This consists of a square frame composed of iron rods, each 4 meters long. To these are attached triangular pieces of cloth of such mesh as is desired, from that as coarse as canvas to that which contains 6,000 apertures to the square centimeter.

These triangles meet at a common apex, thus forming a huge pyramid. This is lowered by a steel cable operated by steam-power. To fish at 6,000 meters the cable must be 10,000 meters long to allow for its oblique line when the boat is moving. When the boat stops the net is drawn up very slowly and carefully. At 5,000 meters depth the columa of water above the top of the net would have a volume of 80,000 cubic meters, and every drop of this vast amount must be filtered through the meshes of the net. The resultant catch contains all the plancton existing in that vast bulk. Devices have also been invented for securing the catch from a given layer at a given depth, shutting off the top layers, but as yet have worked imperfectly.

Oil Filters

ACCORDING to the *London Times* a form of oil filter and drier designed by the British Thomson-Houston Company, of Rugby, is specially intended for the purification of oil used in transformers and other high-tension oil-filled apparatus, though it can also be used for the treatment of many other liquids as well as heavy viscous compounds, the latter being preferably warmed. The importance of dryness in transformer oils is illustrated by the fact that the quantity of water present must not exceed 0.001 per cent in order to obtain a dielectric strength of 40,000 volts in the standard test (0.1 inch between disks 1 inch in diameter), as required for high-tension work. Fine dust, especially metalic, is almost as effective as water in reducing the dielectric strength, and it is, therefore, necessary to remove any sediment which may result from long continued heating, in order to preserve the normal viscosity of the oil and to prevent incrustation of the interior parts of the transformer and the clogging of the oil channels. In the B. T. H. arrangement the oil is pumped under a pressure of 25 to 100 pounds per square inch through layers of pure white blotting paper made principally from wood pulp and supported in a suitable filter press. Most of the solid matter is caught by the first layer of paper, while the water is retained by capillary action in the paper, the capillary attraction between the paper and the water being greater than between the paper and the oil. The presses are made in two standard sizes, one 7-inch, with 14 chambers, having 7 square feet of filtering surface, and the other 12 inches, with 20 chambers, having 30 square feet of surface. Special electric ovens have also been designed for drying the filter paper. The effects of filtering are illustrated by a test carried out on oil which had been in use for about 10 years. Before filtration it broke down at 1,500 volts, with electrodes of 0.05 inch apart; after one filtration it broke down at 10,200 volts; and after a second filtration it withstood 20,000 volts without breaking down.

Importance of Aluminium

IN a paper read before the Junior Institute of Engineers, in England, H. N. Munro calls attention to the increasing importance of aluminium. He stated that for electrical purposes aluminium was fast becoming common. Overhead transmission lines constructed in aluminium showed a great saving over equivalent copper lines, a saving of as much as 10 to 25 per cent being effected, depending on the size and nature of the system erected. The commercial possibilities of aluminium became evident when Hall in America (recently deceased) and Heroult in France produced the metal electrically in 1887.

The Function of Enzymes*

Products of Living Cells That Affect the Chemical Operations of Living Matter

By Samuel C. Prescott

THE study of the chemical or physiological activity of cells, whether of microbes or of men, is at once one of the most interesting and one of the most difficult problems of the biologist, for it seeks to disclose the secrets of life processes. How does a disease germ produce its poison, or a yeast cell bring about its characteristic fermentation? How do we carry on those transformations of food material by which beefsteak and bread and butter at once become available sources of energy and matter for our living machine? How does a potato manufacture starch in its leaves, transfer it to the growing tubers and there store it up for future use?

In each case by means of enzymes, which we may define as the tools of cells and the reagents by which the chemical reactions of cells of all kinds are effected.

The term "ferments" was first used early in the nineteenth century by Schwann and Berzelius. Afterwards the word was used somewhat indiscriminately, meaning either a micro-organism of fermentation or a chemical substance which in some way was related to living cells. To distinguish between these, the physiologist Kühne suggested the term "enzyme" to designate the digestive ferments such as pepsin, trypsin, and ptyalin. The word has now been universally accepted as the name of a group of chemical bodies, products of living cells, which have the peculiar property of effecting the chemical operations of living matter but which do not enter into the final products of these reactions.

Chemistry cannot produce enzymes, for they are found only as the products of protoplasm of living cells, and it makes no difference whether we are dealing with the ultra-microscopic bacterium or the giant redwood or the whale, the chemical activities are due to enzymes. Furthermore, the same kind of enzyme may be produced by organisms of widely different character, as, for example, the trypsin of certain bacteria, of the carnivorous plants like the Venus Fly Trap, and of the human intestinal tract.

Since the variety of chemical processes carried out by living cells is large in number, it follows that the number of enzymes is legion. Even the number produced by a minute bacteria cell hardly visible with a high power of the microscope may be several, while with organisms of highly specialized form and physiological division of labor the number is greatly increased. In man, at least fourteen are known to be developed in the alimentary canal, and to take part in the process of digestion, while, if we added all the other chemical changes which may be elaborated in the body as a whole, our catalogue would be greatly increased. Moreover, we may assume that there are many enzymes which are still unknown, for the enzymes may be intra-cellular, that is, acting only within the cell as well as extra-cellular, or extruded outside the cell and so possibly capable of detection. The positive knowledge of the action of intra-cellular enzymes is still very meager, although when Büchner discovered zymase and a method for its preparation in 1897 the first great step forward in their study was made.

What an enzyme really is, cannot be exactly stated. An enzyme is known only by its reactions. "By their works ye shall know them," is essentially true in the ferment world. We cannot even tell their composition or to what class of chemical substances they belong, for they have never been obtained in pure condition. It is generally assumed, however, without proof, that enzymes are protein-like in character. In spite of this indefiniteness and the elusive character of these bodies, certain general properties regarding them have become known and on these points all enzymes behave in like manner, although differing distinctly from other chemical substances.

We may thus regard enzymes as forming a special and peculiar group of chemical compounds, differing in certain ways from other substances, and especially in their relation to the law of mass action as shown by the great disproportion between the amount of the active substance and the amount of material changed. A good example of this is rennet, which it has been stated can coagulate from 500,000 to 800,000 times its weight of casein, without being used up. All enzymes possess the same characteristic but not necessarily in the same degree. The activity is largely dependent upon the physical and chemical conditions of the environment. Thus very slight changes in the reaction of the medium on which an enzyme is acting may control very largely its power, or make the difference between high efficiency and practical inactivity. Some enzymes require neutral solutions for action, others are most vigorous in slightly acid or slightly alkaline media.

Similarly, temperature may play a very important part in the control of enzyme reaction. In this respect, these substances behave closely like living cells and like certain kinds of proteins. Each enzyme has a maximum, a minimum and an optimum temperature of activity, just as microbes have, and like these, if heated above the maximum, will be rendered inactive and finally destroyed. This thermal death point, as it may be called, is very near the coagulating point of albumin and not far from the death point of most vegetative bacteria. Another similarity to the proteins lies in the fact that both enzymes and albumins are precipitated by concentrated salt solutions such as ammonium sulphate, by alcohol and by salts of heavy metals. Furthermore, they may be more or less completely mechanically precipitated with flocculent or bulky precipitates, as by use of phosphoric acid and lime water. Certain poisons may also inactivate enzymes. Substances which kill living cells, like formaldehyde, hydrocyanic acid or mercuric chloride, will in general "kill" enzymes, provided the solutions used are strong enough and sufficient time is allowed for the destructive action. The enzyme has a somewhat greater resistance than has the living cell, but the difference is one of degree rather than of kind. In fact so closely do enzymes correspond to micro-organisms in behavior toward physical agencies, poisons, etc., that we use the same terminology in discussing them and speak of the "poisoning" or "killing" of the enzyme. Other substances, such as toluene, chloroform, and a few others, permit enzyme reaction but restrain the activity of living cells, this giving a differentiation of great value in studying them.

Enzymes also have many properties in common with the *toxins*, and, so far as body reactions go, seem to belong to the same class of organic compounds. When a toxin is injected in small amount into the body, certain chemical changes are set up, and there is soon formed a so-called antitoxin which neutralizes or inactivates the toxin. Similarly, the action of enzymes upon the tissue of the living body is effected by the secretion of anti-enzymes, and the injection of foreign proteins into the body may be followed by the manufacture of a "precipitin" which will precipitate that particular protein and no other. This specific action is characteristic of enzymes and toxins as well as of proteins. In view of the fact that enzymes and toxins are, like proteins, the products of living cells, it may not be strange that this similarity is found. However, we are not able to say that enzymes are protein in character but rather that they are found in association with proteins. The purest enzymes yet prepared do not give protein reactions. Moreover, mineral salts seem essential for their action.

We may explain the mechanism of fermentation and putrefaction changes on the basis of the enzymes produced by the inciting organisms, for in recent years it has been shown that the enzymes, carefully prepared and fed from living cells, will carry on the same changes with almost mathematical precision. In yeast, for example, Büchner found within the cells an enzyme which could only be extracted by grinding with fine sand and subjecting to enormous pressure, but which, when thus obtained, produced alcohol and carbon dioxide from sugar in exact accordance to the chemical equation which had long been used to represent the fermentation. Thus it was shown that intra-cellular enzymes exist, and we now believe that many processes taking place in living cells—perhaps all the processes—are the results of enzyme activity.

Since the chemical nature of enzymes is so largely unknown, we can classify them only by their action on various compounds. It is possible, however, to group them into the four classes of *hydrolyzing*, or causing the addition of water to certain substances. Most enzymes acting on carbohydrates are of this class. So also are those that affect fats, and the majority of those producing known proteolytic changes. These are best represented in the processes of digestion. A second group are the *Zymase*, or those producing the splitting of bodies into simpler cleavage products without any hydration. The alcoholic fermentation is the best known of this class.

The remaining two classes are the *oxidizing* and *reducing* enzymes, producing the types of change implied. Of the former, the production of vinegar is a familiar example, alcohol being oxidized to acetic acid by an *oxidase* produced by the acetic bacteria. Such familiar changes as the darkening of freshly cut surfaces of fruits (apples) or the quick change of color when mushrooms and toadstools are broken also belong to this category. The reduction processes are of enormous variety in nature, both in plant and animal life. While typically distinguished by the reduction of hydrogen peroxide to water and oxygen, these Katalases, as they are called, may also reduce sulphates, nitrates and various coloring matters as well as other compounds. Upon the activity of enzymes may depend all the complex series of changes, oxidations, reductions, synthetic and analytic changes which characterize the process of growth and decay, renovation and destruction in the cell and in tissues. The phenomenon on intra-cellular fermentation seems to be closely linked with enzyme activity, and the building up and breaking down of protoplasm itself is intimately connected with intra-cellular changes and energy liberation.

There is reason to believe that some enzyme actions are like organic chemical reactions, reversible. Thus, maltase will split maltose into two moleculars of dextrose under the ordinary conditions of action. If, however, we add maltase to concentrated dextrose solutions a small amount of maltose (or isomaltose, a similar sugar) will be formed, the reaction proceeding until a certain equilibrium is established. This has not been demonstrated for all enzymes, and some eminent authorities divide enzymes into two classes, only one of which is catalytic and capable of synthesizing as well as splitting substances, while in the other no trace of synthesis has been observed.

On the subject of the origin of enzymes and the causes stimulating their activity, many interesting observations have been made. Some enzymes are produced by cells in such form as to require no further aid to render them active. Others require the presence of a specific substance known as an activator. The pepsin of the stomach is produced by the cells of the gastric glands as a zymogen called pepsinogen, which, under the influence of the hydrochloric acid produced at the time the stomach is functioning, becomes changed to pepsin. We do not know how the enzyme and the acid are associated but we know that the latter is necessary for the production of pepsin and also for its action. Bayliss has described another instance in which the activator itself, enterokinase, acts as an enzyme upon the zymogen, trypsinogen, thus producing trysin, but without entering into the actual formation of the finished enzyme—trypsin. If this view is correct, we have, in effect, one enzyme bringing a second into existence. In other instances, activation is effected by metals, as in the lac-case, the oxidizing enzyme of the lac tree of Asia, which requires manganese; or by salts, such as phosphates, as in certain alcoholic fermentations.

In spite of the apparent lack of exact knowledge of the composition of enzymes and of all their activities, we find in this group of substances agents which are of direct and certain application to industrial processes. Breadmaking, brewing, cheesemaking, certain phases of tanning, as well as the preparation of lacquers and castor oil, are a few of these applications.

Here is a field of great promise and infinite interest, sure to yield results if investigated patiently and consistently by the scientist who combines a deep knowledge of organic chemistry with an intimate acquaintance with cell behavior and activity, and this field of bio-chemistry is sure to find greater favor in the immediate future.

* From *Science Conspectus.*

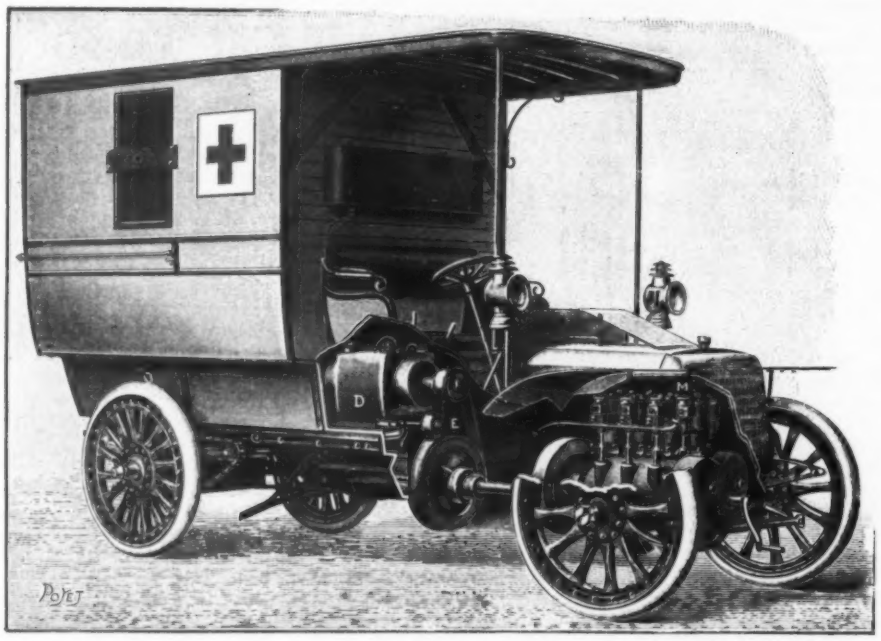
A New Telephone Receiver

AT a recent meeting of the Royal Society a new form of telephone receiver was exhibited that was about the size of a half-inch section of a lead pencil. The specimen shown was made at the laboratory of the University of Utrecht, under the supervision of Prof. Zwaardemaker, and had been in use for several months without showing any signs of deterioration. It is stated that in the new instrument the electro-magnet and diaphragm of the ordinary telephone are eliminated, and for them is substituted a loop of very fine platinum wire within a small cover pierced with a minute hole. As currents pass through the wire they cause small increases and decreases of heat, and the consequent expansions and contractions of the surrounding air become evident as sound. Owing to the smallness of the receiver it can be put in the ear, and sounds are not confused by extraneous noises, while the faithfulness with which the intonations of the voice are transmitted is remarkable. The whole apparatus is more compact than the ordinary instrument and the cost is low.

Roentgenology in War

How Modern Science is Brought to the Field of Action in War

VERY soon after the Roentgen rays became known attempts were made to apply this branch of diagnosis to wounds. Such experiments were tried as long ago as 1896 by the Italians in the Abyssinian campaign; then in 1897, during the Greco-Turkish war, Küttner made use of the Roentgen rays in examinations at the Yildiz hospital at Constantinople, as did also Abbott, who was surgeon on the Greek side, at Phalerus. After this work was done on a small scale in the colonial wars of the English, and finally Roentgenology was established on a much stronger basis through its wide use in the Spanish-American war, 1898-1899, and in the Boer war, 1899-1900. The Herero revolt also gave occasion for its employment in the treatment of wounds. Roentgen rays were much used in the Russo-Japanese War, while in the Balkan war there came into active service the most advanced types of portable Roentgen apparatus.



The Gaiffe-Panhard radiographic carriage employed in the great maneuvers of the East in 1904.
M, motor; *E*, starting gear of the dynamo; *D*, dynamo.

An interesting account of the equipment of a military Roentgen outfit, intended for use in the field, is given in *Die Umschau*, by Surgeon-Major Dr. Strauss, head of a Roentgen laboratory, who tells us that a field Roentgen apparatus is decidedly complicated in its make-up. It must be transportable, should meet all the requirements of modern Roentgenology, and requires a large supply of photographic materials as well as a large amount of additional supplies for the taking of photographs, throwing light, etc. It must also have with it a goodly number of extra parts of the apparatus, so that to carry the whole outfit a very large wagon is necessary, as is shown in the cut of the field Roentgen wagon used in the German army. This wagon contains an inductor with a spark 45 centimeters long, which is driven by a current of 20 amperes strength and 65 volts pressure. This current is interrupted by a Wehnelt contact-breaker, the working of the current being regulated by a switchboard. Besides this apparatus the supplementary parts mentioned above are also stored in the wagon. In all field Roentgen outfits the great difficulty is the source of the current. Ordinarily no dependence can be placed on the chance of connection with an electric wire, especially in the eastern seat of war. The current necessary must, therefore, be generated. The only simple way in which this can be done is by a dynamo driven by a benzine motor.

None of the attempts to get around this difficulty have proved really satisfactory. The entire running of the apparatus would be far simpler if it were possible to generate a sufficiently strong current by means of the condenser. Up to the present time, however, the experiments to this end have not been as successful as required for practical use, although Wommelsdorf's labors in this direction have brought the problem nearer solution. The scheme to replace the dynamo and the benzine motor by accumulators must also be abandoned, for after the accumulator is discharged the recharging in the field is an uncertain matter. As a result of all these factors a field Roentgen outfit represents a heavy weight, and consequently there are definite limits to its use. A benzine motor being necessary for the generating of a current, the thought naturally occurred to work out the entire field Roentgen apparatus as an automobile, and thus to unite in ingenious manner the means for generating a current and for moving about. This idea, which at the present time the French have put into practical use, was debated long ago by the Germans, who finally rejected it. The peculiar conditions of a campaign on the eastern border in winter would make the use of an automobile very uncertain, consequently a field Roentgen automobile would frequently be condemned to stand idle. So on this account the Germans decided to place the military Roentgen outfit in a wagon drawn by horses, the wagon externally being somewhat similar to an ambulance.

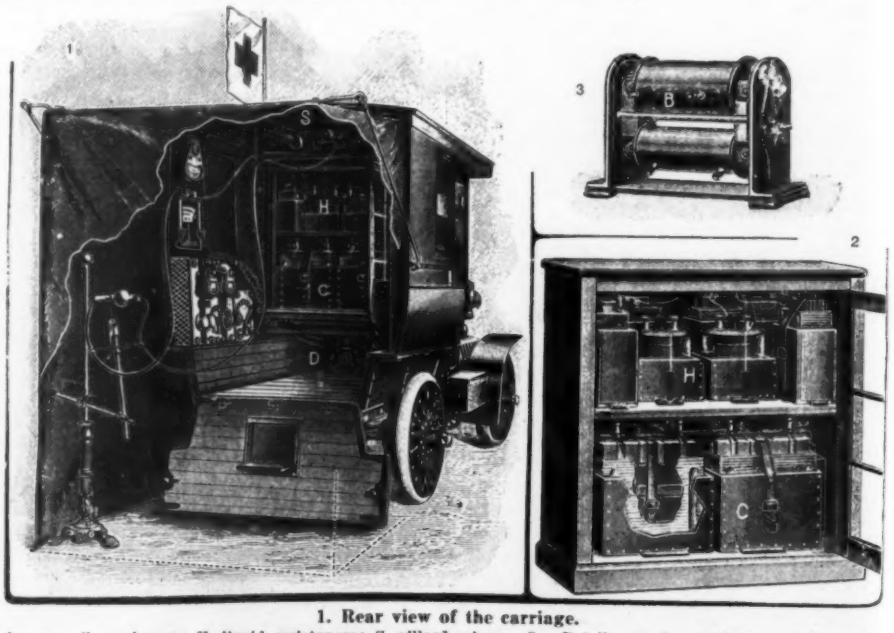
As regards the making of Roentgen-ray examinations in the field, says Dr. Strauss, the many experiences of the campaigns first mentioned show that the Roentgen process is only applicable when it is possible to take definite medical measures. To send the military Roentgen wagon to the spot where first aid is given to the wounded, or to the field hospital, which is often moved five or six times, would be nonsense. All demands that this should be done come from those who neither understand military conditions nor the Roentgen process. Examinations with the Roentgen rays can only be made where quiet and settled conditions prevail. Anything so costly to procure as a field Roentgen outfit should not fall into the hands of the enemy or be destroyed when troops are obliged to fall back. It should also be remembered that the use of the Roentgen rays is a very precise process, and that rough work in the open air without the equipment for a dark room, etc., cannot be thought of. Consequently, these outfits are distributed among the military hospitals. There, where there is quiet and security, the Roentgen process accomplishes positive results.

The chief value in diagnosis of investigation by the Roentgen rays is in the finding of splinters of shot that have remained behind in the body, in the recognition of severe inflammatory conditions in the bony structure, as the dying of some part of a bone or suppuration, and in the determining of injuries to the skull. This naturally brings up the entire question of the value of diagnosis by these rays in internal medicine, as well as, to some degree, of the curative power of the Roentgen rays.

The number of Roentgen outfits taken into the campaign by the German army is relatively large, and the equipment is so complete that salutary work is possible in those parts of the field of war away from ordinary means of communication.

Baskets for German Ammunition

ONE of the many details developed by the German army is what appears to be a new idea in the rapid handling of ammunition for all classes of artillery. In shipping shells, when they are being sent to the front, it is not customary to box or crate them, and they are by no means easily handled on account of their construction, especially the larger sizes. Moreover, if not protected in some way they are liable to injury. To meet these conditions the Germans have made baskets of various sizes, according to the size of the shell to be handled, the largest size containing a single projectile. Other baskets are made in various shapes, with receptacles for shells and cartridges. All the latest patterns of baskets for transporting shells have eight strips of hard wood, four on the outside and four on the inside, extending from the top to the bottom of the basket. The outside strips protect and strengthen the basket, and the inside ones keep the shell in place. Two strips of canvas belting are attached to a circular leather bottom upon which the shell rests, the outer ends of the strips being fastened together, forming a hold by which the shell is lifted from the basket. Baskets are made in various sizes, some with divisions to accommodate cartridges. The baskets are kept filled with shells and cartridges at the artillery depots, ready for quick shipment to the front. The baskets protect the shells and explosives from contact with hard substances as well as facilitating their rapid handling. Within the last few years upward of 1,500,000 baskets have been made for the German army, and before the war large numbers of baskets were sent to Austria and Turkey.



1. Rear view of the carriage.
D, dynamo; *C*, condenser; *H*, liquid resistances; *S*, villard valves. 2. Details of the condensers and resistances. **3. High-tension transformer.**

Effects of Vacuum on Performance of Steam Turbines

In a paper by Mr. G. Gerald Stoney, read before the Institution of Mechanical Engineers, discussing the effect of variations of vacuum on steam turbine installations on land and at sea, and published in the *London Times*, the author said:

The degree of vacuum which gives the same velocity ratio at the exhaust end as throughout any given turbine is the vacuum under which the best results are obtained; consequently a turbine designed for 29 inch vacuum, barometer 30 inches, requires more rows of blades or wheels than one designed for 27 inches, the number of rows or wheels on a given diameter in each case being proportionate to the British thermal units available in the range between the initial and final pressures and temperatures through which the turbine works. There may, however, be considerable latitude in the velocity ratio at the exhaust end without seriously affecting the available economy.

GAINS DUE TO HIGH VACUUM.

The percentage gain due to vacuum depends on the steam conditions, being much more with low-pressure than with high-pressure steam, and the gain in British thermal units available is almost independent of the steam conditions. In other words, for each degree Fahrenheit that the temperature due to the vacuum is reduced there are approximately 1.5 more British thermal units available. These gains, due to vacuum, are wholly attainable when the turbine can be suitably designed, but for high-speed, large output land turbines allowance must be made for increased terminal losses.

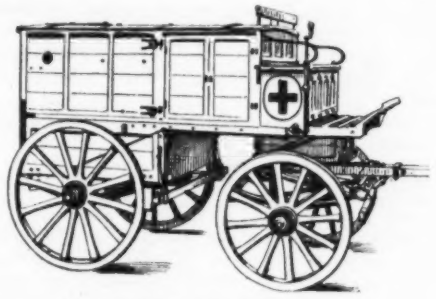
For example, in a 3,000 kilowatt land turbine at 3,000 revolutions per minute, with an initial pressure of 175 pounds, 150 deg. Fahr. superheat and a vacuum of 29 inches, the consumption will be about 121 pounds per kilowatt-hour, and the steam per hour will be 36,000 pounds, or 10 pounds per second. The volume at exhaust, allowing for condensation, will be about 6,000 cubic feet per second. With present materials available it is not in general customary to go above about 550 feet per second for the mean velocity of the blades at the exhaust end, giving a mean diameter of 42 inches, and as the blade height in practice cannot be more than one-fifth of this, or 8.4 inches, the area of the annulus is 7.7 square feet. The velocity of the steam leaving the blades through the restricted area will then be 780 feet per second and involve a loss of 12 British thermal units, assuming that the velocity ratio and angle of the blades is such that the steam leaves them axially, as it should, to give the minimum loss. Even under these conditions, however, there is still a gain of 6½ per cent between 28 inches and 29 inches vacuum. For still larger powers, however, these effects become more pronounced, until conditions are eventually reached in this class of turbine having a highly restricted exhaust end when an increase in vacuum causes no gain. It is the constant aim of designers to increase the limiting vacuum by using higher blade-speeds, and enabling an exhaust end of larger dimensions to be employed, and this is undoubtedly a direction in which increased efficiency in large power, high-speed turbines is to be found.

The effect of increased blade-speed is very marked, as for a given vacuum the reduction in available gain varies inversely as the fourth power of the blade-speed, since as the blade-height cannot well be more than one-fifth of the mean diameter of the blades the area at the exhaust will vary as the square of the diameter, or as the square of the mean blade velocity. Therefore the longitudinal velocity varies inversely as the square of the mean blade velocity, or the British thermal units lost inversely as the fourth power. Of course, the reduction can be halved by adopting a turbine with double flow at the exhaust, but this often introduces complications, although many highly economical land turbines of large power have been designed on these lines. Something can also be done by shaping the exhaust suitably, so as gradually to reduce the velocity of the steam on leaving the blades.

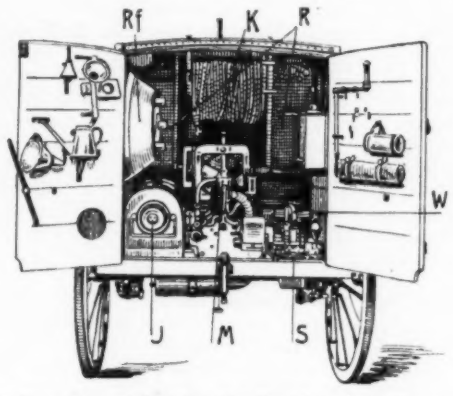
DIRECT-COUPLED AND GEARED TURBINES.

Direct-coupled marine turbines especially, from considerations of weight and space, are often bladed so as to give uniform velocity ratio at full speed with about 26 inches vacuum, and from various causes many land turbines have been similarly bladed. In turbines so bladed and with ordinary steam pressure, it has been found by experience that the gain per inch of vacuum at full load is, between 26 inches and 27 inches, 4 per cent, or 12 British thermal units; between 27 inches and 28 inches, 5 per cent, or 17 British thermal units; between 28 inches and 28½ inches, 6 per cent, or 22 British thermal units; and between 28½ inches and 29 inches, 7 per cent, or 27 British thermal units. In the turbines so bladed and at constant speed, as in land work, the velocity ratio at the exhaust end would automatically become at half-load uniform with the rest of the turbine at about 28 inches, and for quarter-load at about 28¾ inches. Hence in general the theoretical gains will be completely obtained at reduced loads.

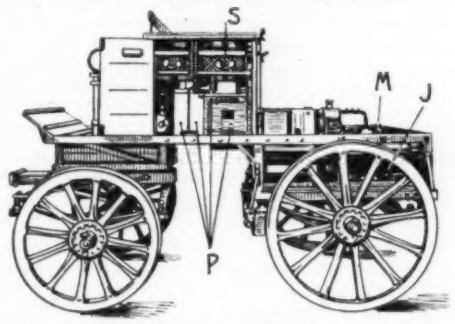
Geared turbines can stand and should be bladed for high vacuum, and the blading should be for nearly the highest vacuum obtainable in the waters in which the ship trades, as there is but little loss by running a turbine bladed for high vacuum at a lower one. For example, it should be bladed for 28½ inches to 29 inches, the vacuum obtainable in home waters and the like, and not for 27½ inches to 28 inches, which will be the vacuum obtainable in the tropics with a good condensing plant. In such turbines the full theoretical gain due to vacuum will be attained at full speed, while at half speed and one-eight power the gain due to increased vacuum will be somewhat more than that at full speed.



1. German Roentgen field wagon.



2. Rear view of interior of a Roentgen field wagon.
J, inductor; *K*, cable; *M*, motor; *R*, tube case; *Rf*, reflector; *S*, switchboard; *W*, contact-breaker.



3. Side view of interior of a Roentgen field wagon.
J, inductor; *M*, motor; *P*, photographic apparatus; *S*, switchboard.

In most cases blading a geared turbine for high vacuum as compared with low vacuum adds very little to the weight, and generally only necessitates the exhaust end being made somewhat larger. It is very important that the exhaust between the turbine blades and the condenser should be free, and should be unrestricted, so that the loss of vacuum between the last row of blades and the steam space in the condenser should be a minimum. This applies to all classes of turbines. It is equally important that the loss of vacuum between the steam space in the condenser and the air-pump suction should also be a minimum. In other words, given a condenser and an air-pump of the highest efficiency, the difference in vacuum between the air-pump suction and exhaust end of the turbine should be reduced to an absolute minimum.

TREATMENT OF EXHAUST STEAM.

In a complete installation, whether land or marine, there are many other factors besides the turbine to be taken account of. As increase in vacuum is associated with a corresponding lower temperature of condensate, it follows that if the vacuum is raised and the condensate is delivered to the boiler at the same temperature at which it leaves the condenser either the quantity of steam generated in the boiler per unit of coal is decreased or the quantity of coal per unit of steam generated is increased. In practice, however, both on land and at sea, the condensate is invariably heated either by the waste gases from the boiler or by the exhaust steam from the auxiliary engines, or by both. Land installations usually include an economizer in the boiler uptake, and the practical requirements in such a case is that, in order to prevent sweating on the tubes, the feed water should be delivered to the economizer at a temperature of about 120 deg. Fahr. But even at the highest vacua there is usually sufficient exhaust steam from the auxiliaries to raise the condensate to this temperature, so that such a system represents the highest economy attainable with any given plant.

Marine installations present a different problem by reason of the large quantity of exhaust steam available from the auxiliary engines, and it may here be noted that the heat in exhaust steam is used to the greatest advantage possible when it is re-delivered to the boiler with the feed water. It follows that in order to attain maximum economy on shipboard the entire exhaust from auxiliary engines should be condensed by the feed-water. A perfect installation from this point of view would be one in which the turbine works under the highest attainable vacuum with efficiency, and in which the exhaust steam is maintained at such pressure as will enable its heat to be wholly transferred to the feed-water. In fact, the economic pressure for the auxiliaries to exhaust at is that in which the whole of their exhaust can be condensed by the feed. Obviously there should be no surplus exhaust, and if there is a surplus it should never be discharged into the main condenser, because of the highly prejudicial effect of oil on the heat-transferring efficiency of the condenser tubes and on the vacuum.

The direction in which progress is to be made on marine turbine installations would, therefore, appear to be: (*a*) High vacuum turbines; (*b*) high efficiency condensing plant; (*c*) economical auxiliaries; and (*d*) efficient exhaust-steam feed-heaters. In some cases where there is a surplus of auxiliary steam it is turned into the low-pressure turbine. Here there is an apparent partial recovery of the loss, but in practice this arrangement has the defect of fouling both the turbines and the condenser with oil and reducing their efficiency, so that the entire power of the turbine may easily be reduced to a far greater extent than it can be increased by the use of such surplus steam. If the steam is used in this way it should be very carefully filtered.

CONDENSER DESIGN.

The effect of reduced conductivity of the condenser, such as is caused by air, is much more at high rates of condensation than at low, showing that the effect of a faulty air-pump or dirty condenser is much more when the rate of condensation is high. Approximately also the loss of vacuum below that theoretically obtainable depends only on the rate of condensation and on the amount of air insulation, and not on the quantity of circulating water, and always assuming a condenser free from oil on the outside of the tubes and scale on the inside, there is not much use in having more circulating water than about 60 to 80 times the steam condensed at full load in home waters and the tropics respectively. Money put into a condenser of ample size is money well spent. Ample surface also gives a good margin to allow of the condenser getting dirty or for overloads.

Fire-resisting Wood

The British Fire Prevention Committee have issued a report on a test they carried out on a partition made of wood which had been impregnated by the Oxylene process with the object of making it fire-resisting. The partition measured 10 feet by 9 feet, and its head, sill, side posts, and intermediates were constructed of 2-inch by 1⅞-inch deal, each side being covered with ⅝-inch grooved, tongued and beaded boarding in 5-inch widths. It was submitted for 45 minutes to temperatures that rose to 1,630 deg. Fahr., and then water was pumped upon it from a steam fire engine. According to the official observations smoke appeared through the joints on the outside after 38 minutes, and scorching was noticed at several joints two minutes later, while after 44 minutes a glow was visible at four joints. Water came through several of the joints, when at the end of the test the hose was turned upon the partition, which, however, remained in position. Although the resistance of the woodwork did not last long enough by a few minutes to enable the partition to be classed as affording "temporary protection," under the committee's standards, a note prefixed to the report states that the test demonstrates that the impregnating process employed has a retarding effect on combustion, and that timber so treated should be a valuable addition to the stock of fire-resisting materials. The process consists in submitting wood to a course of steaming, vacuum, and pressure, whereby the sap-water, air, and moisture are removed and replaced by a chemical solution which is preservative, antiseptic, non-hygroscopic, and non-corrosive. The water of this solution is then evaporated by placing the wood in drying kilns, the chemicals being left embedded throughout the fibers of the wood in minute crystal form. On the application of heat the crystals expand and form a glassy coating to the wood, this coating excluding the oxygen of the air and preventing combustion.—*London Times.*

Iron Manufacture by Electrolysis*

Properties and Industrial Applications of the Product

By L. Guillet

THE industrial manufacture of iron by electrolysis is a problem which has engaged attention for many years, but it is only within the last year that it has entered the practical stage. In principle, the method consists in the use of a revolving cathode and a neutral solution of iron salts, maintained in the neutral state by the circulation of the liquid over the surface of the iron. The bath also receives periodic additions of a depolarizing medium, such as oxide of iron, the object of which is to eliminate, at least in part, the hydrogen deposits on the cathode, which injuriously affect the material if present in too large a quantity. By these means it is possible to work with a current of high density (1,000 amperes to the square meter), and an iron of excellent quality is obtained. The process is applicable either to the production of very pure iron, which can compete with the best iron and Swedish iron, or to the direct manufacture of tubes and sheets in the finished state. It has emerged from the laboratory stage, and is now being put into operation on an industrial scale.

Commercial tubes of electrolytic iron.

PROPERTIES OF THE METAL.

Using any pig iron in solution, an electrolytic iron can be obtained of the following average composition, after removal of the gases by annealing:

	Per Cent.
Carbon	0.004
Silicon	0.007
Sulphur	0.006
Phosphorus	0.008

At the present time it is possible to guarantee phosphorus lower than 0.010 per cent. With a density of current of 1,000 amperes per square meter, the yield per kilowatt-year is 2 tons of metal, including the cost of current for the accessory services, particularly for the rotation of the cathodes.

The material in the crude state, that is, in its state on removal from the electrolyte bath, is hard and brittle. In fact, two effects are produced in the process of manufacture. The metal is interstrained and has absorbed gases, particularly hydrogen. On heating in vacuum between 800 and 1,100 deg. Cent. for four hours, and then raising it to the neighborhood of 1,400 deg. Cent. for a further two hours, Sir Robert Hadfield found that 34 grammes of the iron had a volume of 4.3 cubic centimeters and yielded 28.8 cubic centimeters of gas of the following composition:

	By Volume. Per Cent.	By Weight. Per Cent.
Hydrogen	18.8	65.3
Carbon monoxide	7.4	25.7
Carbon dioxide	0.2	0.7
Nitrogen	2.2	7.6
Oxygen	..	..

The presence of carbon monoxide is somewhat noteworthy. On its removal from the electrolyte, the iron is very brittle, and has a Brinell hardness of 193, using a ball of 10 millimeters diameter under a load of 3,000 kilogrammes. The micrographic examination reveals an entirely characteristic structure, consisting of innumerable fine needles, very much resembling martensite.

After annealing for two hours in magnesia at 900 degrees, the iron shows a Brinell hardness of 90. The micrographic structure is perfectly normal. The tensile test gives a breaking strength of 30.9 to 32.8 kilogrammes per square millimeter, and an elongation of 40.2 to 42.1 per cent in the direction of the axis of the tube. Further, the annealed tubes, when subjected to compression tests, can undergo deformation to an extraordinary degree without a sign of any fracture, as shown in one of the illustrations.

INDUSTRIAL APPLICATIONS.

The industrial applications of electrolytic iron fall into three principal categories: (1) the direct manufacture of tubes; (2) the direct manufacture of sheets; (3) the preparation of pure iron as a raw material intended for fusion. There are various other uses of less importance, such as the preparation of rods of very pure iron for autogenous welding.

Tubes.—The manufacture of tubes is being proceeded with on an industrial scale by the Bouchayer & Vialiet Company, whose installation is capable of turning out 100 tubes per day. The current practice of this company is to manufacture tubes 4 inches long, 100 to 200 millimeters in diameter, with a thickness of 0.1 to 6 millimeters. Some of these are shown in one of the illustrations. As is well known, all present methods of manufacturing tubes present certain insurmountable difficulties when it is desired to obtain regular thicknesses of less than 6 millimeters. As a general rule, in the products obtained the thickness of the wall is far from constant. With the electrolytic process it is possible to obtain the most satisfactory regularity whatever the thickness, diameter, and length of tube.

The tubes will withstand considerable pressures. Thus, a tube of 100 millimeters diameter and 0.75 millimeter thickness, subjected to 1,200 pounds per square inch, underwent a permanent deformation of a regular character, as if squeezed in a press. Another specimen of the same tube was exposed for two and a half months to a temperature of 120 degrees in a boiler. It was then tested to 1,200 pounds per square inch, but no trace of fracture was perceptible.

Sheets.—The manufacture of sheets is under investigation, but no doubt the researches in the industrial laboratory will lead to a method by which they can be produced commercially. The importance of being able to obtain sheets direct without rolling will be appreciated. The iron is of first-class quality, capable of undergoing very considerable deformations in the cold. Tests on tubes and plates have been made in the draw bench, and it is surprising with what facility the metal can be worked. The material is therefore highly suitable for purposes of stamping, both in the form of plain annealed plate (black plates) or of tinned plate. Finally, on account of their purity, these sheets are especially adaptable for use in the construction of electric machinery. Dr. Max Breslauer of Berlin has demonstrated the important aspect of this question, both from the point of view of magnetic properties and of regularity of thickness and compressive strength. The efficiency of alternating motors and transformers, and also of direct current motors, is increased by using this material in their construction. He concludes that the use of electrolytic iron constitutes a real progress, both as regards hysteresis and permeability. In transformers the saving in weight of material is 33 to 40 per cent. The capacity of alternating motors can be increased by 50 per cent, running at the same temperature, and occupying the same space. In direct current machines, 16 per cent of the iron can be saved.

As a Raw Material for Fusion.—Without doubt electrolytic iron will be able to compete successfully with Swedish iron. The quality is much more regular, and the crude metal, being very brittle, can easily be broken into pieces of any required size, however small, and, at the same time, it can be supplied in suitable thicknesses. The cementation of such products would be more regular than those ordinarily used. Tests made at various steel works have shown that tools and special steels manufactured from this material give results at least equal to those obtained with Swedish iron. The cost price is the only remaining consideration.

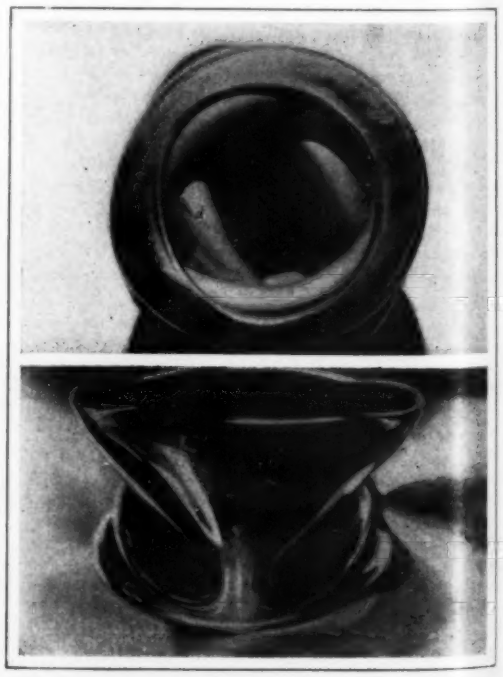
COST OF MANUFACTURE.

The principal factors which make up the cost price are the electric energy and the pig iron. It has already been mentioned that 2 tons of extremely pure iron can be produced per kilowatt-year. Using a current of 500 amperes per square meter, instead of 1,000 amperes, the voltage drops to about one half, and the production per kilowatt-year is nearly doubled. Working with a still lower density, the yield can be even further increased. In countries where the cost of motive power is high, it would pay to work at 500 amperes or even less. It would then be possible to produce 3 to 4 tons, and even more, per kilowatt-year. If the cost of the unit be taken at 1 centime (0.1d.), an ordinary figure in the Alps, and using a current density of 1,000 amperes, the cost of current would not exceed 43 francs per ton of iron produced. Since pig iron is used as the raw material, it may be reckoned that there is about 10 per cent of waste in the form of sludge, graphite, etc. The price of the pig iron would vary according to the locality, and in the mountainous country it would run at about 64 to 88 shillings per ton. The price, however, would be higher in those localities where the electric current was cheapest, and *vice versa*. The average outlay on pig iron per ton of electrolytic iron would therefore be from about 72 to 80 shillings. To this would still have to be added the cost of labor, maintenance, cost of electrolyte, depreciation, and interest on the capital cost of the plant. These various amounts have not yet been definitely ascertained, but the total cost price, based on current prices for material and labor, of the electrolytic iron, in the condition in which it leaves the electrolyte bath, would probably not exceed £6 to £7 12s. per ton, according to the locality.

COMMENTS BY SHERARD COWPER-COLES.

The secretary of the Iron and Steel Institute makes public the following as the substance of a communication sent to him by Sherard Cowper-Coles of Sunbury-on-Thames, England, in which exceptions are taken to some statement in Prof. Guillet's paper:

Mr. Sherard Cowper-Coles wrote that he considered



Result of crushing tests on electrolytic iron tubes.

* From a paper prepared for the abandoned fall meeting of the Iron and Steel Institute at Paris. The author is professor of metallurgy at the Conservatoire National des Arts et Métiers, Paris. Reproduced by courtesy of *The Iron Age*.

the paper by Mr. Guillet very misleading in some of its statements. In 1908 he (Mr. Cowper-Coles) read a paper before the Iron and Steel Institute entitled "The Production of Finished Iron Sheets and Tubes in One Operation," describing in considerable detail his electrolytic process for the direct production of iron tubes, cylinders, and sheets. In that process a mandrel revolving at a critical speed, so as to give sufficient skin friction between the electrolyte and deposited metal was employed to obtain a close homogeneous deposit and at the same time enable a high current density to be employed, the solution being kept neutral by bringing it in contact with iron oxide as described in Mr. Guillet's paper. In the following year, Mr. Boucher approached him (Mr. Cowper-Coles) regarding the process and asked if he would grant him a license to work it in France and Switzerland. This was done, and a small trial plant was thereupon set up in Switzerland and Mr. Boucher produced a number of tubes. A company was ultimately formed, called Le Fer, to acquire the license that had been granted to Mr. Boucher.

Mr. Cowper-Coles's object in setting out these facts is to show that all the preliminary work was carried out in Great Britain at great expense and much labor. That that was so could hardly be gathered from what he thought was a somewhat ungenerous statement which constituted the only reference to the process in Mr. Guillet's paper:

"In 1907 Mr. Cowper-Coles took out a patent involving the use of a 20 per cent solution of sulphocresylate of iron and endeavored to manufacture weldless tubes, using a rotating cylindrical mandrel. This process which was analogous to the Elmore process for making copper tubes has not yielded results of much importance."

The Cowper-Coles process, he continued, is in no way analogous to the Elmore copper process which consists in using an agate burnisher. He thought it should be known that the process described in Mr. Guillet's paper had been worked out in England, and that works are to be erected in the Midlands to carry out the process on a commercial scale. He (Mr. Cowper-Coles) had all the necessary documents for proving the statements he had given.

Business Aspect of the Kelp Proposition*

By Frederic P. Dewey

It is thoroughly well established that the giant kelps of the Pacific provide an enormous store of KCl. Various papers have appeared upon the broad, general aspect of the question, but for the most part they have dealt in glittering generalities and many of them have started in the middle of the proposition. Many writers neglect or slur over the gathering and preliminary drying of the kelp, and base their real consideration of the subject upon the air-dried material. This is very attractive and easy to do, but the cost of the air-dried kelp is a most serious business consideration.

There are various technical and business problems connected with the matter. Without in the least doubting the eventual solution of these problems, it may be said with entire safety that their solution with financial profit will require the expenditure of much time and money, under the best technical and business direction, and that it must be several years before KCl from kelp can become a commercial commodity, if it ever does.

The consideration of the subject divides itself naturally under the following heads:

Harvesting the kelp.
Air-drying.
Oven-drying.
Distillation.
Crystallizing KCl.
Marketing.

To start with the growing kelp. How can it be harvested?

It will be an entirely new industry and manifestly various machines of different types will have to be constructed and subjected to actual practical tests before an efficient and economical machine is secured. Dr. Cameron has suggested 1,000,000 tons of KCl as a conservative annual yield. This would mean the harvesting of approximately 30,000,000 tons of kelp. This harvesting cannot extend over the whole year. Just how long it may last cannot yet be definitely known, but in any event the vast machinery required to harvest 30,000,000 tons in a short season must stand idle a good part of the year at a heavy interest charge against the product.

Having brought the kelp to shore it must be dried. To produce a ton of KCl, approximately 27 tons of water must be evaporated. Clearly the most inexpensive natural means for drying must be adopted, but even this would require the construction of drying sheds covering an enormous area and the building of especially designed machinery to distribute the wet kelp on the drying shelves and to gather up the dried stuff. As with the harvesting machinery, these sheds and machinery must remain unemployed a good part of the year.

There is, however, a limit to the extent that natural drying in open sheds can be carried. When about 25 tons of our 27 tons of water have been evaporated, provision must be made to protect the effloresecing KCl which will soon be produced on further drying. This will require the application of artificial heat. It may possibly be assumed that this can be obtained from the kelp itself in a subsequent operation. By proper oven-drying it is possible to recover 40-50 per cent of the KCl as effloresced salt by simply shaking it off from the dried kelp.

The recovery of the balance of the KCl from the dried and shaken kelp requires the breaking up of the organic matter of the kelp body and this must be done with as full as possible utilization of its value. Simple burning with the utilization of its heat value only will not be sufficient, even if we now had a furnace adapted to avoid inclosing unburned material in the inorganic salts by sintering and to avoid undue loss of KCl by volatilization.

At present, there does not seem to be any method available for this part of the work except destructive distillation with the recovery of the condensable by-products and the utilization of the gas, first to heat the retorts, and secondly, for the oven-drying of the kelp as far as may be. Probably there are no technical difficulties in this operation, but it must be remembered that only about half of the weight, including the effloresced KCl, of the oven-dried kelp is organic matter. In other words, broadly speaking, in the production of one ton of KCl only one ton of organic matter is available for the production of by-products of distillation. On the other hand, the total production of such by-products in the recovery of 1,000,000 tons of KCl would be so large that much of them would have to be transported long distances to find a market and therefore the profit of the operation would largely depend upon freight conditions.

Undoubtedly a limited amount of the residue from the retorts could find direct application as a fertilizer within a certain radius, but the real market for KCl is on the Atlantic coast, and under the present freight conditions of 80 cents per 100 pounds the KCl must be dissolved and recrystallized. Upon the opening of the Panama Canal and the expected halving of the freight rates, the distillation residue might possibly better be shipped direct.

The mother liquors from the recrystallizing of the KCl will contain iodine and when sufficiently enriched they may be treated for the recovery of this element.

It would be a liberal estimate to assume that the by-products recovered, including the iodine, would have a value sufficient to pay for all of the operations upon the air-dried kelp. If we do this and also assume that after sufficient trial and development of the necessary machinery the kelp can be harvested for 25 cents per ton and air-dried for 15 cents per ton more, a ton of KCl laid down on the Atlantic coast would cost $28 as follows:

Harvesting 30 tons at 25 cents	$7.50
Air-drying 30 tons at 15 cents	4.50
Freight 1 ton at 80 cents per 100 pounds	16.00
	$28.00

On the completion of the Panama Canal it is expected that the freight will come down to $8 per ton, but the present prices of KCl must be very profitable to the German Potash Syndicate, and if actually faced with the possible loss of its American trade the prices would undoubtedly be reduced. This reduction might even wipe out the advantage of the low water-freight.

In conclusion it would appear that the feldspars have not yet been displaced by the kelps as a possible source of potash.

* From the *Journal of Industrial and Engineering Chemistry*.

Parsons Marine Turbines

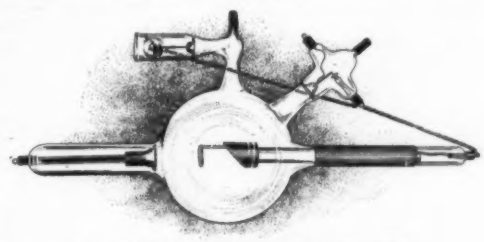
The total horse-power of marine turbines of the Parsons type completed and under construction in England and elsewhere amounts to about 12,360,000 horse-power, an increase during the last 12 months of about 1,760,000 horse-power, according to a statement in the *London Times*. Of the total nearly 10,520,000 horse-power is, or will be, employed for the propulsion of warships, and over 1,850,000 horse-power in mercantile vessels and yachts. The use of geared turbine machinery for ship propulsion is extending rapidly, and 126 vessels built or building are wholly or partly fitted with such machinery, of an aggregate of about 1,000,000 horse-power. These include 62 vessels of 620,000 horse-power ordered during the past year by the Cunard, White Star, Canadian Pacific Railway, Union of New Zealand, Ellerman, and other lines.

New Hydrogen X-Ray Tube

By H. Clyde Snook

Following extended research work in the Snook-Roentgen laboratories, at Philadelphia, Pa., comes the announcement of the development of a new type of X-ray tube, known as the hydrogen tube. Results from its use in a number of disinterested Roentgenological laboratories over a period of several months would seem to indicate that the new type of tube possesses important points of superiority over other X-ray tubes in use at the present time.

One of the most frequent and annoying defects in X-ray tube construction in the past has been the difficulty encountered in adjusting the vacuum to a satisfactory working condition. The most striking characteristic of the new hydrogen X-ray tube is found in the fact that it can be regulated either up or down as to vacuum both accurately and quickly.



The Snook-Kelly hydrogen X-ray tube.

The vacuum is lowered by means of the osmosis of chemically pure hydrogen through a metallic tube, closed at one end, which acts as an osmotic membrane when heated to redness. This metal tube is sealed into the main wall of the vacuum chamber, its open end communicating with the vacuum. Its closed end protrudes into a body of hydrogen contained within a small glass chamber attached to the bulb proper. The metal tube is heated to redness by passing the current across a short spark gap.

To raise the vacuum a similar tube within the raising attachment is heated to redness by the same means. Although, under normal working conditions, the hydrogen pressure within the vacuum (so called) is but .0001 to .000001 millimeter of mercury absolute pressure, it behaves according to the well-known principle that "gases act like vacuums to each other." Atmospheric air is excluded from the vacuum by the metallic tube—yet when the tube is heated, as described above, hydrogen is discharged osmotically into the atmosphere by its own pressure. Hydrogen in minute quantities, therefore, actually passes outward from the vacuum when the raising attachment is in operation. The vacuum of the tube is thereby raised in accordance with the length of time the operation is continued.

Roentgenologists report that the hydrogen tube displays marked stability and disinclination toward heating, due, presumably, to the fact that hydrogen possesses the lowest atomic weight of all known gases and displays little chemical avidity for most metallic substances. Extraordinary penetration has also been noted, comparative radiograms showing one Benoist number higher than with any other type of tube.

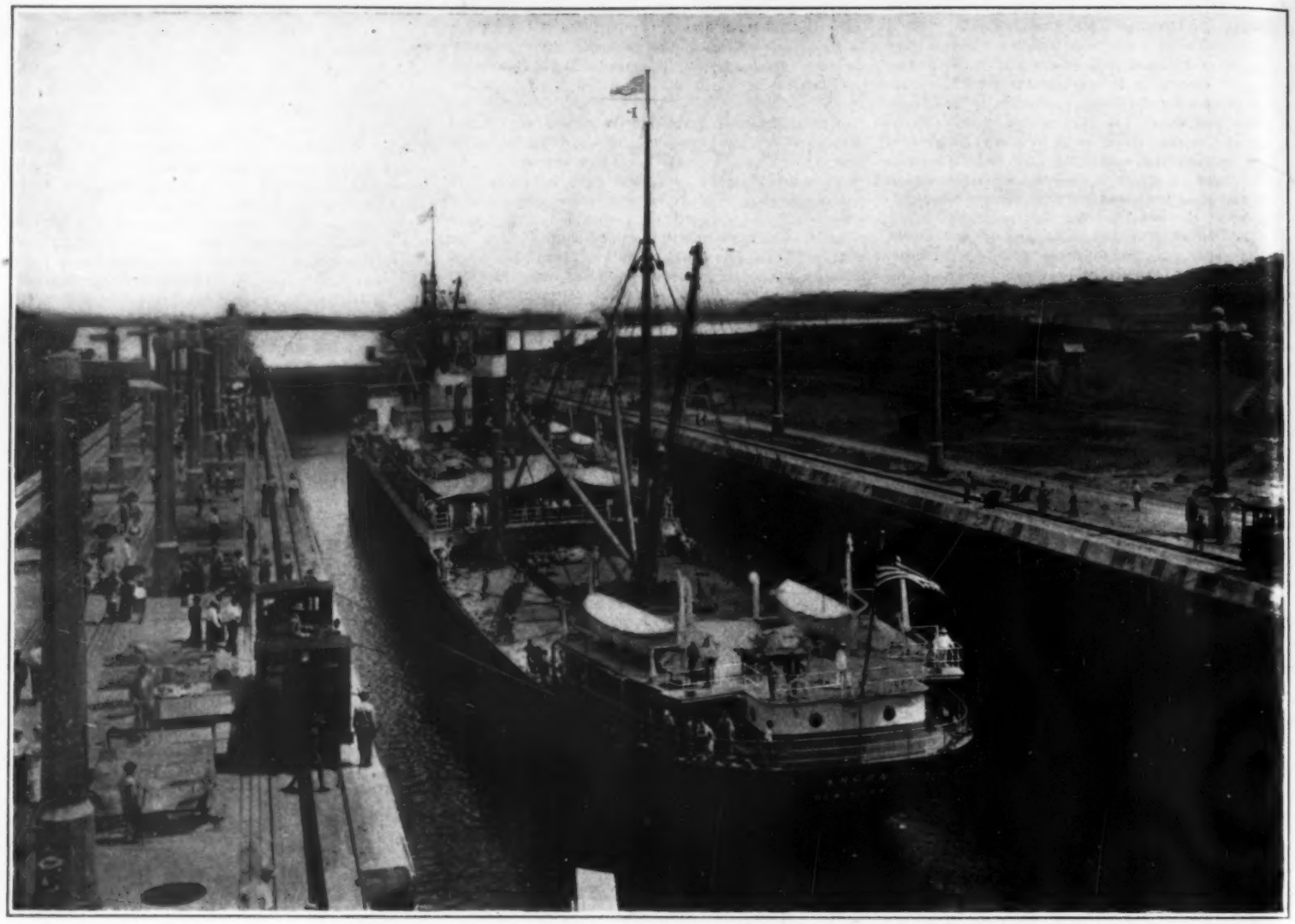
Greater efficiency, more uniform result, and longer life appear, therefore, to be the advantages of the hydrogen tube as demonstrated to date.

Simultaneously there has been evolved, in the same laboratories, an air-cooled type of hydrogen tube, with its vacuum subject to regulation by the same means as the standard type referred to above. By the use of the air-cooled hydrogen tube long fluoroscopic work may be punctuated by making radiograms and administering X-ray therapy in massive doses as frequently as the operator may desire.

The hydrogen tube is the result of joint work by Mr. H. Clyde Snook and Mr. Edwin W. Kelly.

Electro-chemical Generators

The Neuhausen Aluminium Works recently ordered three electric generators for an increase in their large plant at Chippis in the Swiss region. These machines are built by the well-known Oerlikon Works, and are to be ranked among the largest yet to be constructed for electro-chemical use, being of 2,650 kilowatt size, or 3,850 horse-power. Such machines deliver as much as 8,000 amperes, at a tension of 340 volts, and the standard speed is 300 revolutions per minute. The generator in each case is direct coupled to a hydraulic turbine, and it is built to stand an overload up as high as 3,000 kilowatts, while if necessary the speed can be increased to nearly twice the standard, or to 540 revolutions per minute. As far as we know, the present machines appear to be not only the first to be built, at least in Europe for such a large output and as heavy a current with a relatively high speed, but appear even to be the largest generators yet to be built on this side for electro-chemical purposes.



Vessel in the upper Gatun lock as seen from the balcony of the control house.

Electric Towing in the Panama Canal Locks

Ingenious System and Novel Electric Locomotives

INVESTIGATIONS of collisions between ships and lock gates invariably show that "there was a misunderstanding in signals between the captain and engineer." Bearing in mind that the engineer of a ship is so situated that he does not know the exact position of the ship, with respect to the lock, he cannot check his actions by the probable result. A system, therefore, which permits checking the movement of the ship with the signal given by the pilot or captain of the ship, will eliminate improper manipulations to a very great extent.

Various systems are in vogue at drydocks, which are based on the principle that the operator sees the result of his action. The employment of winches, or capstans, has been looked upon with a great deal of favor. These are usually placed at intervals along the dock walls, and the lines from the ship are carried forward to the successive capstans as the ship advances. Such a system involves the risk of the ship not being properly safeguarded when the lines are transferred to successive capstans. An improvement has been made by the installation of a capstan at the head of the dock, centrally located, and used for imparting a straight motion to the ship. Numerous lines from the ship to the dock wall are carried by men; and the capstans are employed to counteract any wind pressure, currents, etc., and assist generally in maneuvering the ship. While an improvement over former methods, it did not, however, possess the flexibility and reliability required for the operation of the locks of the Panama Canal. Neither would it have eliminated the breaking of the lines at critical moments, which is regarded as one of the essential requirements in successfully handling ships in canal locks.

After a very thorough study of the entire problem of maneuvering ships through the locks of the canal, it became evident that they should not proceed through the locks under their own power, and that a substitute for the ship's power should embrace the following requirements:

(*a*) Ability to place the ship in proper relation to the lock.

(*b*) Capability of keeping the ship to its course.

(*c*) Accelerating and retarding the ship without rupturing the lines.

(*d*) The lines when once attached should be used without change for lockage in flight.

(*e*) A small number of skilled operators rather than a large number of unskilled men to co-ordinate.

The towing system described in the following pages was designed and patented by Mr. Edward Schildhauer,

Method of attaching the electric locomotives to a vessel for towing through a lock.

electrical and mechanical engineer of the Isthmian Canal Commission; and the forty towing locomotives and all the electrical apparatus for operating the locks, were built by the General Electric Company.

TOWING SYSTEM.

In passing through the canal from the Atlantic to the Pacific, a vessel will enter the approach channel in Limon Bay, which extends to Gatun, a distance of about 7 miles. At Gatun it will enter a series of three locks in flight and be raised 85 feet to the level of Gatun Lake. It may then steam at full speed through the channel in this lake, for a distance of 24 miles, to Bas Obispo, where it will enter the Culebra Cut. It will pass through this cut, which has a length of nine miles, and reach Pedro Miguel, where it will enter a lock and be lowered 30 feet. Then it will pass through Miraflores Lake for a distance of 1½ miles, until it reaches Miraflores, where it will be lowered 55 feet through two locks, to the sea level, after which it passes out into the Pacific through an 8½-mile channel.

The main features of all the lock sites are identical; and the following brief description of the Gatun Locks, with special reference to the arrangement of the towing tracks, ship channels, inclines, and approaches, gives a conception of the towing scheme.

There are two ship channels, one for traffic in each direction, which are separated by a center wall, the total length of which is 6,330 feet. There are two systems of tracks, one for towing and the other for the return of the locomotive when returning idle. This, however, refers only to the outer walls. For the center wall there is only one return track in common for both the towing tracks. The towing tracks are naturally placed next to the channel side, and the system of towing requires normally not less than four locomotives running along the lock walls. Two of them are opposite each other in advance of the vessel, and two run opposite each other following the vessel, as seen in line cut on this page. The number of locomotives is increased when the tonnage of the ship demands it.

Cables extend from the forward locomotives and connect with the port and starboard sides, respectively, of the vessel near the bow, and other cables connect the rear locomotives with the port and starboard quarters of the vessel. The lengths of the various cables are adjusted by a special winding drum on the locomotive to place the vessel substantially in mid-channel. When the leading locomotives are started, they will tow the vessel; while the trailing locomotives will follow and keep all the cables taut. By changing the lengths of the rear cables, the vessel can be guided; and to stop the vessel, all the locomotives are slowed down and stopped, thus bringing the rear locomotives in action to retard the ship. Therefore, the vessel is always under complete control quite independent of its own power, and the danger of injury to the lock walls and gates is very greatly lessened.

The illustrations show how effectively the four locomotives keep the vessel under control and in the center of the channel, and give a general idea of the method of handling vessels. They also show general views of the lock walls, towing tracks and the inclines, the steepness of the latter being especially noticeable.

The towing tracks have a specially designed rack rail

extending the entire length of the track and located centrally with respect to the running rails. It is through this rack rail that the locomotive exerts the traction necessary for propelling large ships and climbing the steep inclines.

A rack rail is also provided on short portions of the return track so as to lower the locomotives safely from one level to the next. The steepest slope is 26 degrees, or 44 per cent, hence the need will be seen for rack rail even on the return track, it being noted that any traction locomotive with the usual wheel drive, even with the brakes set, would begin to slide on a 16 per cent grade, and, therefore, could not be controlled. With a rack rail, however, traction is limited only by the capacity of the driving motors and not by the adhesion of the wheel treads on the rails.

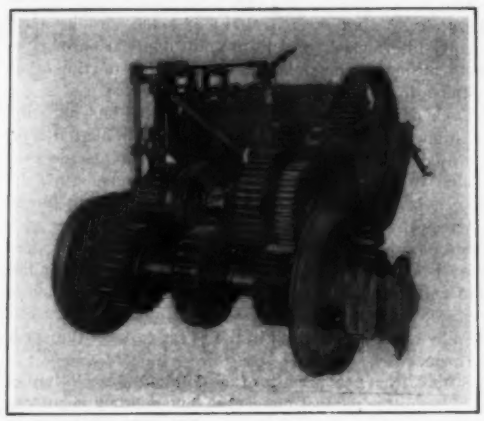
The rack rail is of the shrouded type, and each tooth space has a drain hole cast in the bottom so as to carry off water and other accumulations to suitable drain pipes or ducts set in the concrete of the walls. A further feature of the rack rail is the projecting edges, which permit thrust wheels attached to the locomotive to run along the under side and prevent overturning of the locomotive, in case some unforeseen operating condition should produce an excessive pull on the towline. These thrust wheels serve to counteract the lateral component of the towline pull and the flanges act for emergency only, as the weight of the locomotive is, however, sufficient to prevent overturning with a normal pull of 25,000 pounds on the towline.

Three-phase, 25-cycle, 220-volt alternating current is used for operating the locomotives, and the current is supplied to the locomotives through an underground contact system. Two T-rails form two legs of the three-phase circuit and the third leg is formed by the main track rails. A specially designed contact plow slides between the two "T" conductors and transmits the power from the rails to the locomotive. This contact plow also passes through the slot opening in the conduit cover and is flexibly connected to the locomotive in such a manner as to follow all irregularities in the tracks and crossovers, and, therefore, insures a continuous supply of power.

LOCOMOTIVE DESIGN.

The working parts of the locomotive are supported by two longitudinal upright side frames of cast steel, connected by transverse beams. These frames are in effect deep rigid trusses, having upper and lower members connected by posts and diagonal braces. The pedestals for the wheel axles are of the usual locomotive type. Springs are interposed between the tops of the journal boxes and the tops of the pedestals, and the locomotive is thus mounted upon four wheels, the wheelbase being 12 feet, and the overall length of the locomotive over 32 feet.

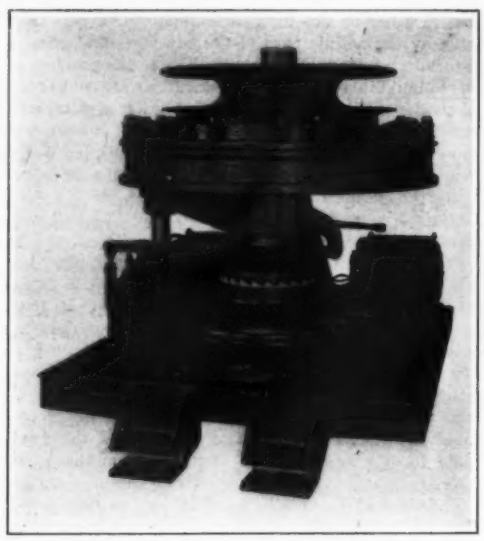
Each axle is driven by its own independent motor; and, as the construction is identical at both ends of the machine, a description of one will suffice for both. The motor is of the three-phase, slip-ring type, inclosed and identical to the rugged steel mill design. The motor is carried on a pair of cast steel suspension brackets, which are journaled on the wheel axle at one end, and located just inside the wheel on either end of the axle. The other ends of these brackets are connected by yielding supports to one of the cross members of the main frame of the locomotive. These brackets



Traction motor unit of one of the Panama electric locomotives.

also carry two countershafts with the necessary gearing and clutches for transmitting the power from the motor to the wheel axle, with the proper reduction of speed. On the wheel axle is keyed a gear wheel, through which the locomotive can be driven by the traction of the wheels on the rails. The wheel axle also carries a loose sleeve on which is mounted a gear wheel meshing with the transmission gear from the motor, and also the heavy cog wheel that engages with the track rack for propelling the locomotive when engaged in towing. On the second countershaft are arranged clutches by means of which the power can be transmitted either to the wheels for traction running or to the rack pinion. The locomotive is operated on the traction only when running without load and between inclines.

The two traction motors are controlled by suitable controllers installed in the cabs at the ends of the locomotives; and the circuits are such that both motors can be controlled from either cab, and can be operated singly or in multiple as desired.



Mechanism of the windlas that handles the towing cable.

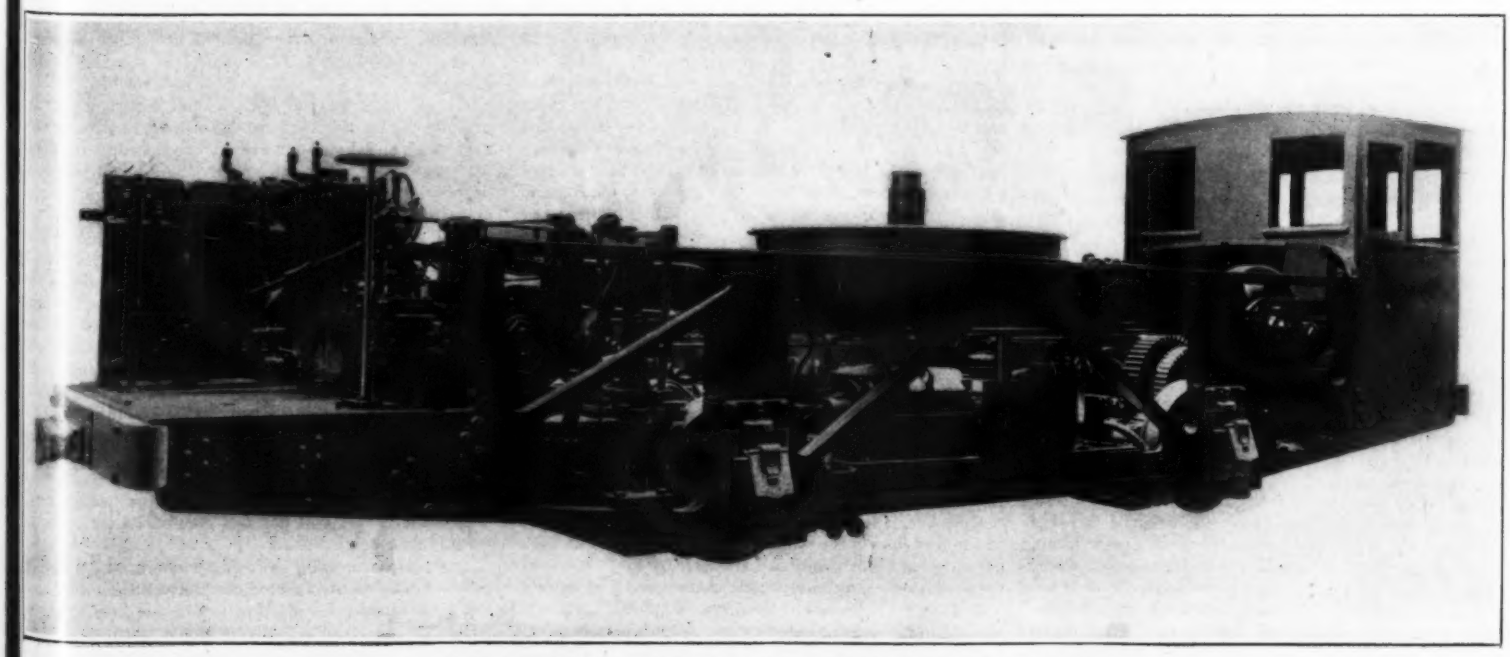
In connection with each motor a powerful brake is installed; and, as during operation the motors are at all times geared either to the axles or to the cog wheels, the truck wheels are not provided with any brake rigging.

These brakes are operated by a solenoid, the winding of which is in circuit with the controller of the motors, so that when the current is turned on to energize the motor windings, the solenoid will lift its core and thereby release the brakes. The first point of the controller raises the brakes without applying power to the motors, thereby providing a coasting point. But should the motor current be shut off, either intentionally or accidentally, the core will instantly drop by gravity and its weight will exert a powerful leverage upon the brake levers to stop the motor and the locomotive. This action occurs simultaneously on both motors, and brake action is powerful enough to stop the locomotive within two revolutions of the wheels.

In addition to this automatic brake, means are provided for applying the brakes manually in order to supplement the action of the automatic feature, if necessary, when descending a grade or where approaching a rack rail.

Passing now to the features which render the locomotive peculiarly adapted for towing purposes, it is observed that there is a large horizontal drum mounted above the body of the locomotive at its middle length, which handles the towing cable that is wound upon it. This drum is carried on a heavy tubular column that is fixed in a substantial pedestal built into the main frame of the locomotive. Below the drum, and mounted on the same column, is a large internally geared wheel, which is connected to the drum by a slip friction clutch, consisting of a steel disk held between two alloy rings with a yielding pressure produced by a series of coiled springs. Two separate electric motors are provided for operating this towing drum, one driving through bevel and spur gearing to the large internally geared wheel, which is for fast coiling in or paying out the cable. The other motor drives through a worm gear, and thence by a spur gear onto the same internally geared wheel, clutched with the towing drum, and is used for taking in slack of the cable, and controlling vessels when towing. The fast running gear is always connected, but the slow working power gear is connected by means of a clutch, which is thrown out automatically by a solenoid that is energized by the movement of the controller governing the fast winding motor. The first point of the controller energizes the solenoid, and frees the clutch of the power gear, and the second point starts the coiling motor.

One of the most important parts of the locomotive is the "slip-friction" device consisting of the two special alloy rings, and the steel disk fastened to the rope drum, the amount of tension on the tow line being adjusted by the pressure between these three disks, which is obtained by tightening the spiral springs on the clamping ring. In order, therefore, to make the slipping tension of the towline proportional to the pressure between the friction disks, a rubbing surface having an absolutely constant coefficient of friction is essential. To find such a metal, certain tests were made and showed



Electric towing locomotive with casing removed, showing its construction.

that the low friction metal, having a friction coefficient of 0.1, is practically constant under all pressures and condition of the surfaces, and, therefore, was selected for the work. This metal also showed but very little difference in coefficient between starting and running. The results of the special tests were furthermore amply verified by the final test of the friction disks of each machine under full rated towline pull of 25,000 pounds. All forty machines were given this slip test twenty-five times from each cab, and all passed the Government requirement not to exceed a variation of 5 per cent above or below the normal of 25,000 pounds.

In connection with the slip test, further data on the slow winding motor was obtained. The winding motor is a 20 horse-power (one-hour rating), three-phase, high torque, squirrel cage type, induction motor controlled from a drum type reversible controller in either of the two cabs. And it has ample power to take care of any sudden pull on the towline up to 40,000 pounds, which is well above the normal requirement of 25,000 pounds. The speed of winding is at the average rate of 12 feet per minute.

The rapid-coiling motor is permanently geared to the drum, and is of the same type, size and capacity as the winding motor. It is subjected to its maximum load when accelerating the heavy drum to the high speed required for coiling or paying out the rope, this being sixteen times the slow winding speed at full load, or about 200 feet per minute.

The slow-winding and the rapid-coiling motors are operated by similar controllers and the circuits electrically interlocked so as to prohibit application of power to either motor unless the controller of the other motor is in the "off" position.

Each of the two main traction motors has a rating of 75 horse-power, and is of the slip ring induction type, operated by a system of contactors with master controller in each cab. The motors, by means of the change in gearing from straight traction to rack rail towing previously described, drive the locomotive at a speed of 2 miles per hour when towing and 5 miles per hour when returning idle. These motors act as induction generators running above synchronous speed when the locomotive is passing down the steep inclines and thereby exert a retarding brake effect to keep the speed uniform.

Space does not permit of a detailed description of the locomotive control apparatus, but a fairly good idea will be had by reference to one of the illustrations.

SUMMARY.

The towing locomotives, as described and illustrated, possess the following operating characteristics:

1. While towing, the speed can be regular from zero miles to two miles per hour.

2. While running idle, the speed can be regulated from zero to five miles per hour, permitting return trips at increased speed.

3. The windlass will pay out or wind in cable at the low rope speed and at the full tow line pull of 25,000 pounds, either when the locomotive is running or at rest.

4. The windlass will pay out or coil in cable at the high rope speed with the tow line taut, either when the locomotive is running or at rest.

5. The windlass is equipped with a safety friction device, which is adjustable to any predetermined value of the tow line pull.

The first impression may be gathered that these machines are somewhat complicated; but, considering their many functions and the great flexibility for performing them, the design is in reality peculiarly simple. The locomotives have fully demonstrated in actual operation that the requirements contemplated by the Isthmian Canal Commission have been successfully met.

The locomotives have a net weight of 86,300 pounds and a gross shipping weight of 92,500 pounds.

During the first three months of commercial operation of the canal, from August 15 to November 15, the cargo transported through the canal and towed through the locks by the locomotives amounted to 1,079,521 tons. During the fiscal year ending June 30, 1914, the Panama railroad carried 643,178 tons of through freight between the two seaboards, and in the preceding fiscal year 594,040 tons. From this it is seen that between six and seven times as much cargo is passing over the Isthmus now as passed over this route when goods were trans-shipped by rail.

The Hygienic Home

Some Facts About Ventilation and Fresh Air

By Dr. John B. Todd

THE home is the foundation of all society; its organization is the objective realization of the wisdom and culture of its founders. The ideal home is that in which, with the means available, there is an adjustment of environment that will result in health, comfort and future development of all members of the family. In the establishment of an ideal home it is not so much what one does, or does not do, but rather whether in a given environment and within one's means one does really those things that count for health and comfort.

One of the primal conditions necessary for an ideal home is the perfect health of all its members. The first wealth is health, for while there are exceptional cases where an indomitable will is able to overcome the handicap of ill-health—as in the case of the illustrious Darwin—still, with perfect health much more could be accomplished. Of the conditions in a home that are factors in producing ill health and disease, the matter of ventilation is very important. Probably poor ventilation in houses, schools, churches and all other indoor places where people spend more or less of their time, is the cause of more deaths and more ill-health than all of the wars. The effect of living in ill-ventilated rooms is very insidious and slow to be noticed, but it is none the less fatal in its results. Sanitarians have made many experiments trying to find out just what it is in bad air that is bad, but their results so far have been unavailing. Their methods are too clumsy. According to their beliefs carbon dioxide—the product of respiration—is not harmful. The foul smelling odors that we notice in close rooms produce no ill effects, rebreathing air is not unsanitary, that the bacteria we take in through the air is of a negligible quantity, that the breathing of dusty air is not bad unless in some trades, as grinders of metals, pottery, etc.

The fallacy is in trying to find bad air by considering and excluding the constitutents one by one. In the same way there is no such thing as a wagon, for when we inquire:

Is the pole the wagon?
No.
Is the box the wagon?
No.
Is the seat the wagon?
No.
Is the wheel the wagon?
No.
Is the axle the wagon?
No

we fail to find the wagon; but when one is knocked down and run over by a wagon, there is no question of its existence. Thus when we consider the diseased conditions that exist among people who habitually breathe bad air, there is no doubt of its reality. First, we find a slow but steady lowering of resistance, the color of the skin is pale and not of the clear, ruddy tinge of people living out of doors, there is sub-oxidation, the stale indoor oxygen has lost its vitality, and in consequence they become easily fatigued. Then anaemia follows as the precursor to a host of diseases; bronchitis, tuberculosis, laryngitis, rheumatism, and diseases of the digestive system. Price examined 1,413 workers in cellar bakeries and the best tailor shops, and found over two-thirds diseased.

From all these facts it becomes very evident that we need fresh indoor air—air that has had its oxygen made active by the actinic rays of the sun and the buffeting of storms and winds. In the ideal home the problem is, first, to build in a manner that our houses are cold-proof, and therefore it becomes a matter of better architecture. From 25 to 50 per cent of the fuel we burn is wasted to balance the heat loss from our windows, walls and floors. If the heating problem were only to warm the air in our homes, the cost of fuel would be insignificant.

We want windows in great plenty, for light is as necessary as air for healthful rooms, but the heat loss from the windows in enormous. A room inclosed by glass but with no heat is as cold as the outside, and added to the coldness is the stale, dead air with its inactive oxygen. This is the reason of the failure of glass-inclosed sleeping-porches. Air of itself is a nonconductor of heat and we have only to build our homes with two or three air spaces in the walls to make them practically cold proof. Of course all windows, except those having fresh air screens, should have perfect fitting storm sash, and the floors should have a nonconductor filling between the joists. The extra expense of this construction would be returned a hundred fold in health, comfort and money saved. Then, no matter what heating and ventilating system you have, there should be several windows fitted with fresh air screens.[1] These are wood frames made to fit closely the window frame opposite the lower sash in such a manner that all openings for drafts are closed. This frame is covered with a medium quality of unbleached cotton cloth. The lower window is left free and can be raised and lowered as occasion may require. When the window is raised the screen acts as a permeable membrane and allows the fresh air to slowly diffuse into the room and permits no draughts. There is not a day during the cold months of the year when these fresh air screens cannot be used at longer or shorter intervals; and another great benefit from their use is that the air is filtered and dust-free. Dusty air is one of the factors that causes disease and we have greatly under-estimated the evil effects of breathing dust laden air.

There is one part of the home in which we spend one-third or more of our lives, which should receive our earnest consideration to render it sanitary in every respect, and that is the sleeping room. If there is any part of the 24 hours in which we want to be comfortable, it is when we retire to woo sweet sleep, and there is also no part of our time when we really need fresh air and live oxygen as much as we do here, that we may arise refreshed and vigorous. Too often we have not been able to reconcile the idea of comfort and fresh air, and we have taken comfort and let the fresh air go.

However, it is possible and perfectly practical to sleep in comfort during the winter and at the same time have our sleeping room filled with sweet, fresh air. We have only to place a properly constructed fresh air screen opposite the lower sash in one or two windows, then with the windows raised at night we can sleep in perfect safety with the room filled with fresh, invigorating air, and one will arise in the morning with renewed energy. There will be no draughts; rain or snow cannot come in, and the room will not seem cold. Some mothers will claim that this is best for adults, but that it will not do for small children, as they will get uncovered and take cold. Many of these same mothers have learned that it is beneficial for the baby to sleep out of doors in the baby carriage during the day, even through the coldest weather, when the child will sleep quietly and never disarrange the clothing. A little thought reveals the fact that children kick off the clothing nights because they are uncomfortably warm in the heated, close, stuffy sleeping rooms, and that children sleeping under these conditions are habitually getting cold. What we call colds is a germ infection, and hot, stuffy sleeping rooms furnish favorable conditions for its development, while sleeping in cool, fresh air develops the greatest possible resistance to the infection. Mothers should use their reason to fortify their courage, and provide fresh air screens for the children's sleeping rooms. They will not kick off the bedding, but instead will cuddle down and sleep quietly. Their resistance to colds and infections will be increased and they will make more vigorous growth.

If there is any occasion in our lives when we require fresh air more than another it is when we are confined to our bed by reason of illness. It is at this time that the use of fresh air screens gives the greatest comfort and furnishes the greatest aid to recovery. Stubborn, desperate cases of anaemia have much greater chance to mend as soon as continuous fresh air conditions are provided. In pneumonia it is well known that the comfort and condition of the patient are improved under fresh air conditions, and the chances of recovery greatly increased.

We all have learned by personal experience to appreciate the comfort and benefit of fresh air living. We may read and have our reason convinced, our friends may talk fresh air until we have not an objection to propose, still, until our knowledge comes from personal experience, it is of no value to us in our lives. You should acquire that personal experience by having at least one window in your sleeping room fitted with a properly made fresh air screen, for you will quickly perceive the benefit derived, and see the want of more screens. When actual knowledge is acquired in this manner, those who can do so will be satisfied with nothing less than an outside screened sleeping room, which is the greatest convenience, luxury and necessity of an ideal home. All the bed dust is excluded from the home, and the actual housework is very much lessened. The temperature in a sleeping porch during cold weather will be from 12 to 36 deg. Fahr. warmer than the outside. When the outside temperature reaches 45 or 50 degrees, a person will not feel comfortable without an outside door open.

The universal living in fresh air conditions would do more to exterminate tuberculosis than all the other agencies combined, and now that it is made possible to do so by the fresh air screens it would seem that those interested in public health should do everything possible to educate the people to their value.

[1] For details see SCIENTIFIC AMERICAN SUPPLEMENT, Feb. 21st, 1914.

Arithmetical Machines—II*

Their History, Theory and Methods of Construction

By H. E. Goldberg, M. W. S. E.

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 2038, Page 60, January 23, 1915

Key-set Machines.—In the class of key-set adding machines are to be found some of the best known machines, such as the Burroughs and Wales. The Burroughs is constructed about as follows: (Figs. 7 and 8.)

There is a bank of keys for each decimal place. Each bank is provided with keys having the values 1, 2, 3, 4, 5, 6, 7, 8, and 9. Co-operating with the keys of each bank is a bar *A*, which has a series of projections upon it, P^1, P^2, P^3, up to P^9. Notice that P^1 is very close to the bottom of the key 1, in fact, just one step removed. P^2 is two steps from the bottom of the key 2; P^9 is nine steps from the bottom of key 9. There is a spring *C* tending to move the gear bar to the left, but it is prevented from so moving by the interference of the cross bar *D*. When the operator depresses a key, he pushes its bottom into the way of the co-operating projection upon the bar. The operator, having thus set up the keys for the number desired, pulls the handle. This advances the bar *D* to the left, thus removing its interference. The bars *A* follow the bar as far as they can, that is, until each bar hits the projection upon the key depressed in its bank. Each bar is thus advanced a number of steps corresponding to the value of the key depressed. Some of you have already noticed the fact that if no key is depressed there is nothing to stop the gear bar in its advance. It, therefore, would move the maximum amount, say nine. Of course, this must be prevented in an actual machine, and is so prevented by a special stop which prevents the bar *A* from moving, but which stop is pushed out of the way by the pushing down of any key.

Totalizer.—You will notice that Fig. 8 is drawn to a

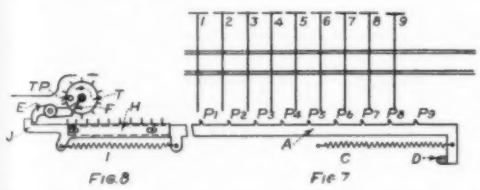


FIG. 8 FIG. 7

larger scale than Fig. 7. This is for the purpose of illustrating the totalizer. During the advance of the gear bars, the totalizer wheels *T* were not in mesh with them. After the bars have finished moving leftward, the totalizer is lowered into mesh with the bars. When the cross-bar *D* is pushed back, it pushes back the gear bars to their original place, and the meshed totalizer wheels are thus rotated an amount corresponding to the value of the keys set up.

Immediately after the rotation of the totalizer wheel by the gear bar, the carrying mechanism operates. The tens-carrying mechanism is constructed somewhat as follows:

Imagine the totalizer wheels *T* mounted on an axle and each wheel provided with a carrying projection *TP*. Between each two wheels is a lever *E* mounted, let us say, friction-tight upon its fulcrum, and having a tooth *F* in the pathway of the pin *TP*. The wheel *T* rotates in the direction of the arrow, and in due time its pin *TP* will strike *F* and push away the lever *E*. This striking and pushing away of the lever is due notice that the wheel has completed a cycle of motion; that is, arithmetically, it should carry a ten into the next higher wheel to the left. Any wheel that should tens-carry will, therefore, have pushed away its lever. Any wheel that should not tens-carry will not have pushed away its lever. The wheels *T* are rotated by the racks *H* upon the bar *A*, which racks *H* in their turn are pulled by springs *I* fastened both to the racks and to the bar *A*. Each rack *H* is provided with a hook *J* that strikes against the end of the lever *E* whenever that lever is in its approached position; that is, as long as the lever has not been pushed away by the wheel. But when the lever *has* been pushed away by the wheel, the hook *J* no longer strikes the lever *E*. Instead, it enters below the lever, and thus moves one step further to the right than it would have moved if it had struck the lever.

Notice that each rack *H* is stopped by the lever *E* which is at its right, which lever in turn is moved by the totalizer wheel *T* at its right. That is, finally, the striking of pin *TP* of a wheel against its lever determines that the wheel next to the left shall receive not only the movement which it would otherwise receive, but also an additional step of movement; that is, the tens have been carried into it.

The above mechanism is almost identical with that used in the Burroughs and the Dalton machines. Variations are found in the Moon-Hopkins and many others. The mechanism as described is irreversible; that is,

Ex. 1	Ex. 2
9999	9999
1	9999
999'0	'8'8'8
99'0'0	'8'8'9'8
9'0'0'0	'8'9'9'8
1'0'0'0'0	1'9'9'9'8
10000	19998

FIG. 9

it will not work if the wheels *T* rotate in the opposite direction. The wheels would be stuck when the pin *TP* would strike *F*. This sticking of the wheel at this point when rotating in the opposite direction is used in the above machines in bringing said wheels to the zero position, as in erasing a number on a totalizer or in the printing of a total. The tens-carrying of this mechanism is, of course, successive. The wheel to the left does not carry until the wheel to the right has done so, but it is very rapid, and in practice but little time is occupied thereby.

A totalizer like the above that accumulates simultaneously, but that carries successively, would digest the examples previously used in the following manner: (Fig. 9.)

Having already in its stomach the first number, 9999, it swallows the second number as a whole, but does not assimilate it immediately. The result as to the first bite would be ('8), ('8), ('8), ('8). The little (') shows that it is a number temporarily stored up to be afterward carried. Mechanically it means that the lever next to the wheel has been pushed away. A series of digestive steps now occur, which successively transform the contents into the number desired. The first digestive step results in the carrying of the units (') into the tens, thus giving ('8), ('8), ('9), 8. That is, the tens rack has moved an extra step. The second digestive step produces ('8), ('9), 98. That is, the hundreds racks has moved an extra step. The third step shows ('9), 998. And the last step produces 19998.

The totalizers of many machines operate on this principle of delayed seriatim carrying.

Any machine whose totalizer would accumulate and carry simultaneously would make but one bite of the whole meal. Thus 9999 and 9999 is 19998. There are no machines on the market whose totalizers operate on that principle, but there are quite a number described among the patents issued in the United States. Let me state here that one mechanical basis for the possibility of accomplishing all the accumulations and all the carryings simultaneously rests on the employment of trains of epicyclic gears.

Ten-key Machines.—Let us go a little further into the theory of the ten-key machines. We noted that

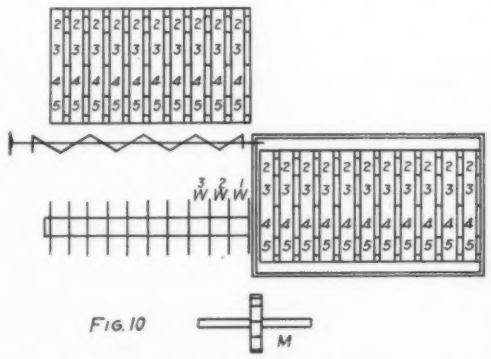


FIG. 10

every totalizer has a set of totalizer wheels, one for units, one for tens, another for hundreds, etc. When on a typewriter a number is printed in a column, as in arranging dollars and cents properly, it is the business of the operator to bring the carriage of the machine to the proper place for the first figure, and from then on they follow in proper order. This readily solves the problem for all typewriter attachments such as the Wahl and the Elliott-Fisher. On some machines, however, as the Dalton and the Moon-Hopkins, there is no carriage which is first decimally placed by the operator. When on such a ten-key machine an operator strikes a 1, how does the machine know that it is a 1? Perhaps it is only the first figure of a number, say 127. Historically, the accomplishing of the result was found difficult, as is shown by the fact that in the earlier machines the inventors put down the figures backward. Thus 127 used to be put down, first 7, then 2, then 1. The first men to show mechanisms which permitted the figures to be written down highest figure first, units last, were Mr. McCaskey and Mr. Helmick, both now of Chicago. The idea occurred to each of them independently, and as they both applied for patents in 1894 some complications arose as to who was the inventor. The means by which they accomplished the result was the introduction of a supplementary carriage capable of storing up a number. (Fig. 10.)

Let there be a series of windows through which numbers become exposed to the operator of a machine. Let W^1 be the units place window, W^2 the tens place, etc. Let *A* be a carriage something like the carriage of a typewriter, and provided in a similar manner with

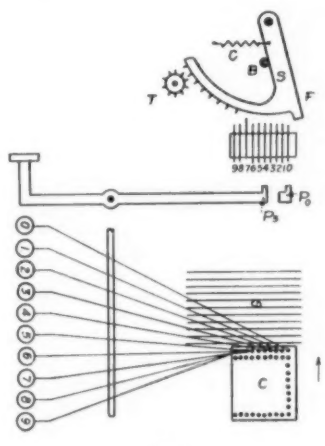


FIG. 11

an escapement mechanism, and having a tendency continually to travel to the left. This carriage is provided with a set of wheels *B*. Let *M* be a master wheel located immediately to the right of the units window. The master wheel *M* is given a rotation corresponding to the figure desired. If the figure is an 8, the master wheel would be rotated eight steps by any suitable mechanism. This master wheel *M* thus rotates the leftmost wheel of the carriage, bringing the figure 8 opposite to the row of windows, but not yet under the window in sight of the operator. When the operator releases his finger from the keys, the escapement mechanism of the carriage causes the latter to advance one step to the left. The 8, therefore, comes into view in the units window. The moving of the carriage has thus brought opposite to the master wheel the next wheel to the right. The pushing down of another key, say 7, by the operator, causes the master wheel *M* to introduce a 7 into this second wheel, and the subsequent escapement and moving of the carriage another step to the left brings this 7 into view in the units window, moving the original 8 into the second window, the whole number now visible being 87. And so on. A set of totalizer wheels *T* is located in alignment with the windows, and the carriage with its wheels is, therefore, brought into alignment not only with the windows, but also with the totalizer wheels. Further operation depends upon the construction of the machine. But in every ten-key machine where it is not the operator that first determines what decimal place is to be operated in, a traveling carriage is provided for storing up the numbers, which carriage travels toward the left. In Fig. 10 the traveling carriage is represented as provided with a set of wheels which are rotated by a master wheel.

Fig. 11 represent the construction of the Moon-Hop-

* A paper read before the Western Society of Engineers and published in the *Journal* of the Society.

kins and the Dalton machines—more particularly the Dalton. There are ten keys, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, which are fulcrumed upon an axis. The back ends of the keys are bent together to form a line, and end in a series of projections, I^a, I^b, I^c, etc. Pushing down the finger piece at the front of the key pushes up the corresponding projection upon the back of the key. Traveling immediately above the projections at the backs of the key levers is a carriage *C* provided with decimal banks of stops, each stop, say, friction-tight in its bearings. The carriage is provided with an escapement mechanism like that of a typewriter. It can thus be seen that when an operator presses, say, key 7, the pin corresponding to 7 will be pushed up as shown in Fig. 11, and the carriage will advance one step to the left, bringing a new bank of stops over the projections that are at the backs of the keys. The keys can then operate upon the next bank of stops, and the number is thus set up upon the carriage.

After the number has been set up upon the stops in the carriage, it is transferred to the totalizer by means of some large sectors *S*, each of which is provided with a finger *F* capable of striking the stop opposite to it in the carriage. Normally, the sectors are held back by means of a bar *B* against the force of the springs *C*; but when the bar is moved, as is done during the pulling of the handle, its resistance is removed, and the sectors advance as far as they can, that is, until they are stopped by the protruded pins in the carriage. In the Moon-Hopkins machine, racks instead of sectors are used; otherwise the mechanism is about the same. The carrying mechanism in both of these machines, the Moon-Hopkins and the Dalton, is similar in theory to that described in connection with the Burroughs machine.

I have given no space to printing mechanism, which is quite a problem in itself, particularly the non-printing of the zeros at the left of a significant figure. Thus, in a machine which has, say, seven decimal places, the number 1000 would have the three zeros to the right of the 1 printed, whereas there would be no zeros printed at the left of the 1. The printing mechanism varies considerably in the machines on the market. As a general principle, the mechanism for the preventing of the printing of the undesired zeros works by preventing the printing hammers from flying to make an impression.

Multiplying and Dividing Machines.—A multiplying and dividing machine differs from an adding machine in that it must preserve the multiplicand that is set up on the mechanism. All multiplying machines, without exception, preserve the multiplicand during the process of multiplication. In adding machines, the addend is destroyed after the first addition. Figure 12 shows a diagrammatic representation of the mechanism of Grant's arithmetical mill. The machine is supplied with a carriage *C* capable of being reciprocated by means of a crank *D*. Mounted in the carriage are a series of racks *R*, each provided with a handle *H*, by means of which the operator can advance it in the carriage to any desired position. In the figure, one of the racks only is shown, and it is advanced four steps. Of course, there is a rack for each decimal place, one for units, one for tens, etc. The operator advances each rack the desired amount, and the machine locks these racks into place in the carriage. The rotation of the crank *D* then advances both carriage and racks toward the totalizer wheels *T*, which are thus engaged by the racks, and each is rotated an amount dependent upon the distance that its particular rack has previously been advanced. There is, of course, mechanism for preventing the rotation of the wheels *T* upon the return movement of the carriage and racks, but into that I shall not enter. Notice that by this means the number set up upon the carriage is not disturbed, but can be used over and over.

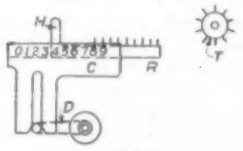


FIG. 12

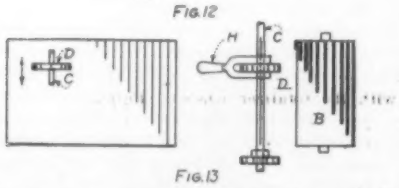


FIG. 13

In Fig. 13 is shown another means that is used in multiplying machines for inserting the number in the totalizer. For each decimal place there is a barrel *B*, part of which, approximately one-third, is covered with teeth which vary in length from a maximum to a minimum, and have the values 9 to 0. Parallel with the axis of the barrel is a square shaft *C*, whereon is slidably mounted a gear *D*, which, by means of a handle *H*, is slid by the operator opposite any desired point. The rotation of the barrel will, therefore, cause the wheel *D* to be rotated a number of steps, dependent upon the number of teeth on the barrel *B* opposite said wheel. That is, it will be rotated only one step when it is opposite the lower end of the long tooth, and nine steps when it is opposite all of the teeth, as at the upper end. The figure to the left shows a development of the surface of the barrel. The reason why the teeth upon the barrel occupy only about one third of the circumference is that the other two thirds is used in the carrying mechanism, which I shall not illustrate at this moment. The above mechanism is the one invented by Leibnitz about 1675 and is now used in the Thomas, the Burkhard, the Tim, the Saxonia, the Archimedes, the Monroe, and many others.

The mechanism in Fig. 14 represents the construc-

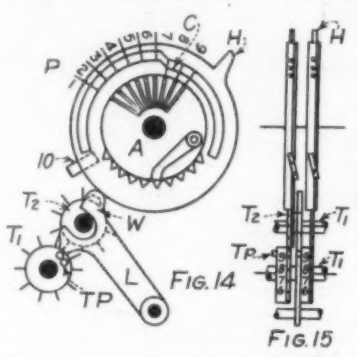


FIG. 14 FIG. 15 FIG. 16

tion of the Brunsviga machine and its brethren, the Thales, the Triumphator, the Marchand, and others. There is a drum *A* capable of being rotated about its axis, and provided in each decimal place with a mechanism like the one before us. In each decimal place there is a rotatable cam provided with a handle *H*, by means of which the operator may rotate it about the axis of the drum *A*. The operator may thus project outside of the circumference of the drum a series of pins *P*, or retract them into the circumference. In Fig. 14 we see that six pins have been projected, whereas three remain below the surface. Mounted upon axes parallel to that of the drum are two totalizer wheels T^1 and T^2, always in mesh with each other, and each provided with ten teeth. It is evident that a rotation given to the drum about its axis will cause the projected teeth or pins *P* to pass by the teeth of T^2 and rotate it an amount dependent upon the number of pins set out. Moreover, this will occur at every revolution of the drum.

Should the drum be rotated in the opposite direction, then the wheels T^1 and T^2 will still be rotated an equal amount, but in the opposite direction, thus accomplishing subtraction instead of addition.

The carrying mechanism of the Brunsviga will now be sketched. Upon the wheel T^1 is a pin *TP*. Co-operating with the pins is a lever *L* mounted, say, friction-tight upon its fulcrum. It is evident that whenever the pin *TP* passes by the lever, it will push it away from the wheel T^2 upward toward the drum *A*. The lever *L* carries a peculiar wedge-shaped piece *W* near the drum. Fig. 16 shows a view of the wedge taken on a plane, including the axes of the drum and the two sets of wheels. Mounted on the drum is a special carrying tooth 10. It is normally held to the right by means of a spring, and in passing will not engage the wheel T^2 to the left. In Fig. 16 are shown two adjacent wheels T^2, two wedges *W*, one to the right and one to the left, and two special carrying teeth 10. The carrying tooth 10 to the right is in its normal position. In passing by the wheel T^2 it would not be interfered with by the wedge *W*. It would, therefore, miss the wheel T^2. Suppose, however, that previous to the coming around of the carrying tooth 10, the wedge *W* had been pushed in the way of the tooth 10, as is shown by the wedge to the left, the tooth 10 would now strike the wedge immediately before striking the wheel T^2. It would thus be shoved to the left, and in passing by would engage and turn the wheel T^2 one step. It would thus rotate said wheel a special carrying step.

In order that the carrying steps upon the various wheels of the totalizer shall not interfere with each other, these steps are made successive. One is completed before the other commences. To accomplish this the teeth 10 are placed in a spiral around the drum. The spiral always operates units first, tens next, etc. This may require that there shall be a different spiral for subtraction than for addition, and in the Brunsviga, the Monroe, and other machines this is accomplished by providing two spirals, one of which is effective for addition, and the other one for subtraction.

The above multiplying and dividing machines multiply and divide by repeated addition and subtraction. In multiplying any multiplicand by, say, 7, the multiplicand is rapidly added seven times. Since the highest possible figure is 9 and the lowest is 1, we might say that the average figure is 5, and that these repeated addition multiplying machines require five steps for multiplying by an average figure. There are, however, multiplying machines which do not operate on the repeated-addition principle. They embody in their mechanism a mechanical representation of the multiplication table.

In Fig. 17 is shown the multiplication table as taught to us in school. Please notice that I have filled out each product until it always contains two figures, one in the tens place, another in the units. Immediately below we see a section of this multiplication table taken through 7, and above that are the products represented mechanically by various lengths of pins, the first pin representing the tens place, and the second pin the units place. For instance, $6 \times 7 = 42$ is represented by a pin in the tens place whose length is 4, and another pin in the units place whose length is 2. The scheme indicated, namely, the representation of the multiplication table by different lengths of pins, was the one first proposed as a mechanical representation of the multiplication table, and was brought out by Leon Bollée, a Frenchman, many years ago—I think in 1896. After him there came many others. Kindly notice that in a multiplication-table multiplying machine it is necessary to perform two additions for each decimal place, namely, the addition of the figures in the tens place and the addition of the figures in the units place. This would seem to indicate that the multiplication-table multiplying machine requiring only two additions per decimal place is about two and a half times as fast as the repeated-addition multiplying machines, which require five additions on the average for each decimal place. In practice, however, the difference is considerably reduced by the special mechanism that must be operated in the multiplication-table multiplying machines, and which do not occur in the repeated-addition multiplying machines.

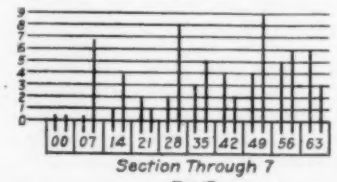
The above refers to the multiplication of a multiplicand by a multiplier of a single figure, say, 4896 by 7. In case the multiplier has more than one figure, it is necessary to move some portion of the mechanism relatively to another to thereby shift the decimal place. This is accomplished on most machines by hand, but on the Moon-Hopkins and Millionaire machines it is accomplished automatically.

Dividing Machines.—Division is ordinarily accomplished mentally by guessing at a trial divisor, attempting the division, seeing whether it is right or wrong, and correcting the result in accordance therewith. This guessing process has not been followed mechanically; in the machines that divide, division is accomplished by continuous subtraction of the divisor and the determination when that divisor has been subtracted a sufficient number of times. In the machines on the market this determination occurs whenever the remainder obtained by the continuous subtraction of the divisor from the dividend becomes negative. That is, it occurs just one step too late. This necessitates one retracing step to correct the error just introduced. The machines, therefore, operate as follows:

Subtract, subtract continually until the remainder becomes negative. This is now one step too far. Therefore, add once to correct this last wrong subtraction and then step down one decimal place, and repeat the process.

In some machines on the market the operator has to watch to see when the remainder will become negative. In others, namely, the Millionaire, the Brunsviga, the

	0	1	2	3	4	5	6	7	8	9
0	00	00	00	00	00	00	00	00	00	00
1	00	01	02	03	04	05	06	07	08	09
2	00	02	04	06	08	10	12	14	16	18
3	00	03	06	09	12	15	18	21	24	27
4	00	04	08	12	16	20	24	28	32	36
5	00	05	10	15	20	25	30	35	40	45
6	00	06	12	18	24	30	36	42	48	54
7	00	07	14	21	28	35	42	49	56	63
8	00	08	16	24	32	40	48	56	64	72
9	00	09	18	27	36	45	54	63	72	81



Section Through 7
FIG. 17

Thales, the Marchand, etc., an audible signal is given by ringing a bell whenever the remainder becomes negative.

You will, therefore, notice that only a reversible multiplying machine can be readily used as a dividing machine.

The Birth-Time of the World*

Methods of Determining Its Age

By Prof. J. Joly, Sc.D., F.R.S.

OF THE earth's origin we have no certain knowledge; nor can we assign any date to it. Possibly its formation was an event so gradual that the beginning was spread over immense periods. We can only trace the history back to certain events which may with considerable certainty be regarded as ushering in our geological era.

Notwithstanding our limitations the date of the birth-time of our geological era is the most important date in science. For in taking into our minds the spacious history of the universe it must play the part of time-unit upon which all our conceptions depend. If we date the geological history of the earth by thousands of years, as did our forerunners, we must shape our ideas of planetary time accordingly; and the duration of our solar system, and of the heavens, becomes comparable with that of the dynasties of ancient nations. If in millions of years the sun and stars are proportionately venerable. If in hundreds or thousands of millions of years the human mind must consent to correspondingly vast epochs for the duration of material changes. The geological age plays the same part in our views of the duration of the universe as the earth's orbital radius does in our views of the immensity of space.

A study of the rocks shows us that the world was not always what it now is and long has been. We live in an epoch of denudation. The rains and frosts disintegrate the hills; and the rivers roll to the sea the finely divided particles into which they have been resolved; as well as the salts which have been leached from them. The sediments collect near the coasts of the continents; the dissolved matter mingles with the general ocean. The geologist has measured and mapped these deposits and traced them back into the past, layer by layer. He finds them ever the same: sandstone, slates, limestones, etc. But one thing is not the same. *Life* grows ever less diversified in character as the sediments are traced downwards. Mammals and birds, reptiles, amphibians, fishes, die out successively in the past; and barren sediments ultimately succeed, leaving the first beginnings of life undecipherable. Beneath these barren sediments lie rocks collectively differing in character from those above; mainly volcanic or poured out from fissures in the early crust of the earth. Sediments are scarce among these materials.[1]

There can be little doubt that in this underlying floor of igneous and metamorphic rocks we have reached those surface materials of the earth which existed before the long epoch of sedimentation began, and before the seas came into being. They formed the floor of a vaporized ocean upon which the waters condensed here and there from the hot and heavy atmosphere. Such were the probable conditions which preceded the birth-time of the ocean and of our era of life and its evolution.

It is from this epoch we date our geological age. Our next purpose is to consider how long ago, measured in years, that birth-time was.

THE AGE BY THE THICKNESS OF THE SEDIMENTS.

The earliest recognized method of arriving at an estimate of the earth's geological age is based upon the measurement of the collective sediments of geological periods, and consists in measuring the depths of all the successive sedimentary deposits where these are best developed. The total of these measurements would tell us the age of the earth if their tale was indeed complete, and if we knew the average rate at which they have been deposited. Thus it is not easy to measure the real thickness of a deposit. It may be folded back upon itself, and so we may measure it twice over. We may exaggerate its thickness by measuring it not quite straight across the bedding or by unwittingly including volcanic materials. On the other hand, there may be deposits which are inaccessible to us; or, again, an entire absence of deposits; either because not laid down in the areas we examine, or, if laid down, again washed into the sea. These sources of error in part neutralize one another. Some make our resulting age too long, others make it out too short. But we do not know if a balance of error does not still remain. Here, however, is a table of deposits which summarizes a great deal of our knowledge of the thickness of the stratigraphical accumulations. It is due to Prof. Sollas.[2]

		Feet.	
Recent and Pleistocene		4,000	
Pliocene		13,000	
Miocene		14,000	
Oligocene		12,000	
Eocene		20,000	
			63,000
Upper Cretaceous		24,000	
Lower Cretaceous		20,000	
Jurassic		8,000	
Trias		17,000	
			69,000
Permian		12,000	
Carboniferous		29,000	
Devonian		22,000	
			63,000
Silurian		15,000	
Ordovician		17,000	
Cambrian		26,000	
			58,000
Keweenawan		50,000	
Animikian	Algonkian	14,000	
Huronian		18,000	
			82,000
Archæan		?	
Total			335,000 feet

In the next place we require to know the average rate at which these rocks were laid down. This is really the weakest link in the chain. The most diverse results have been arrived at, which space does not permit us to consider. The value required is most difficult to determine, for it is different for the different classes of material, and varies from river to river according to the conditions of discharge to the sea. We may probably take it as between two and six inches in a century.

Now the total depth of the sediments as we see is about 335,000 feet (or 64 miles), and if we take the rate of collecting as 3 inches in a hundred years we get the time for all to collect as 134 millions of years. If the rate be 4 inches, the time is 100 millions of years, which is the figure Geikie favored, although his result was based on somewhat different data. Sollas most recently finds 80 millions of years.[3]

THE AGE BY THE MASS OF THE SEDIMENTS.

In the above method we obtain our result by the measurement of the *linear* dimensions of the sediments. These measurements, as we have seen, are difficult to arrive at. We may, however, proceed by measurements of the *mass* of the sediments, and then the method becomes more definite. The new method is pursued as follows:

The total mass of the sediments formed since denudation began may be ascertained with comparative accuracy by a study of the chemical composition of the waters of the ocean. The salts in the ocean are undoubtedly derived from the rocks, increasing age by age as the latter are degraded from their original character under the action of the weather, etc., and converted to the sedimentary form. By comparing the average chemical composition of these two classes of material—the primary or igneous rocks and the sedimentary—it is easy to arrive at a knowledge of how much of this or that constituent was given to the ocean by each ton of primary rock which was denuded to the sedimentary form. This, however, will not assist us to our object unless the ocean has retained the salts shed into it. It has not generally done so. In the case of every substance but one only, the ocean continually gives up again more or less of the salts supplied to it by the rivers. The one exception is the element sodium. The great solubility of its salts has protected it from abstraction, and it has gone on collecting during geological time, practically in its entirety. This gives us the clue to the denudative history of the earth.[4] It is the secret of the sea.

The process is now simple. We estimate by chemical examination of igneous and sedimentary rocks the amount of sodium which has been supplied to the ocean per ton of sediment produced by denudation. We also calculate the amount of sodium contained in the ocean. We divide the one into the other (stated, of course, in the same units of mass), and the quotient gives us the number of tons of sediment. The most recent extimate of the sediments made in this manner affords 56×10^{16} tonnes.[5]

Now we are assured that all this sediment was transported by the rivers to the sea during geological time. Thus it follows that if we can estimate the average annual rate of the river supply of sediments to the ocean over the past we can calculate the required age. Now the land surface is at present largely covered with the sedimentary rocks themselves. Sediment derived from these rocks must be regarded as, for the most part, purely cyclical; that is, circulating from the sea to the land and back again. It does not go to increase the great body of detrital deposits. We cannot, therefore, take the present river supply of sediment as representing that obtaining over the long past. If the land was all covered still with primry rocks we might do so. It has been estimated that about 25 per cent of the existing continental area is covered with archæan and igneous rocks, the remainder being sediments.[6] On this estimate we may find valuable major and minor limits to the geological age. If we take 25 per cent only of the present river supply of sediment, we evidently fix a major limit to the age, for it is certain that over the past there must have been on the average a faster supply. If we take the entire river supply, on similar reasoning we have what is undoubtedly a minor limit to the age.

The river supply of detrital sediment has not been very extensively investigated, although the quantities involved may be found with comparative ease and accuracy. The following table embodies the results obtained for some of the leading rivers.[7]

	Mean annual discharge in cubic ft. per second.	Total annual sediment in thousands of tons.	Ratio of sediment to water by weight.
Potomac	20,160	5,557	1 : 3,575
Mississippi	610,000	406,250	1 : 1,500
Rio Grande	1,700	3,830	1 : 291
Uruguay	150,000	14,782	1 : 10,000
Rhone	65,850	36,000	1 : 1,775
PO	62,200	67,000	1 : 900
Danube	315,200	108,000	1 : 2,880
Nile	113,000	54,000	1 : 2,050
Irrawaddy	475,000	291,430	1 : 1,610
Mean	201,468	109,650	1 : 2,731

We see that the ratio of the weight of water to the weight of transported sediment in six out of the nine rivers does not vary widely. The mean is 2,730 to 1. But this is not the required average. The water-discharge of each river has to be taken into account. If we ascribe to the ratio given for each river the weight proper to the amount of water it discharges, the proportion of weight of water to weight of sediment, for the whole quantity of water involved, comes out as 2,520 to 1.

Now if this proportion holds for all the rivers of the world—which collectively discharge about 27×10^{12} tonnes of water per annum—the river-born detritus is 1.07×10^{10} tonnes. To this an addition of 11 per cent has to be made for silt pushed along the river bed.[8] On these figures the minor limit to the age comes out as 47 millions of years, and the major limit as 188 millions. We are here going on rather deficient estimates, the rivers involved representing only some 6 per cent of the total river supply of water to the ocean. But the result is probably not very far out.

We may arrive at a probable age lying between the major and minor limits. If, first, we take the arithmetic mean of these limits, we get 117 millions of years. Now this is almost certainly excessive, for we here assume that the rate of covering of the primary rocks by sediments was uniform. It would not be so however, for the rate of supply of sediment must have been continually diminishing during geological time, and hence we may take it the rate of advance of the sediments on the primary rocks has also been diminishing. The average rate of supply has therefore been greater than the mean rate. Now we may probably take, as a fair assumption, that the sediment-covered area was at any instant increasing at a rate proportionate to the rate of supply of sediment; that is, to the area of primary rocks then exposed. On this assumption the age is found to be 87 millions of years.

THE AGE BY THE SODIUM OF THE OCEAN.

I have next to lay before you a quite different method. I have already touched upon the chemistry of the ocean, and on the remarkable fact that the sodium contained in it has been preserved, practically, in its entirety from the beginning of geological time.

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[1] For a description of these early rocks, see especially the monograph of Van Hise and Leith on the Pre-Cambrian Geology of North America (Bulletin 360, U. S. Geol. Survey).

[2] Address to the Geol. Soc. of London, 1909.

[3] Geikie, *Text Book of Geology* (Macmillan, 1903), vol. I. p. 73 *et seq.* Sollas, *loc. cit.* Joly, *Radioactivity and Geology* (Constable, 1909), *Phil. Mag.* September, 1911.

[4] *Trans. R.D.S.*, May 1899.

[5] Clarke, *A Preliminary Study of Chemical Denudation* (Washington 1910). My own estimate in 1899 (*loc. cit.*) made as a test of yet another method of finding the age, showed that the sediments may be taken as sufficient to form a layer 1.1 mile deep if spread uniformly over the continents; and would amount to 64×10^{16} tons.

[6] Van Tillo, *Comptes Rendues* (Paris), vol. cxiv. 1892.

[7] Russell, *River Development* (John Murray, 1898).

[8] According to observations made on the Mississippi (Russell, *loc. cit.*)

There is little doubt that the primeval ocean was in the condition of a fresh-water lake. It can be shown that a primitive and more rapid solution of the original crust of the earth by the slowly cooling ocean would have given rise to relatively small salinity. The fact is the quantity of salts in the ocean is enormous. We are only now concerned with the sodium; but if we could extract all the rock-salt (the chloride of sodium) from the ocean we would have enough to cover the entire dry land of the earth to a depth of 400 feet. It is this gigantic quantity which is going to enter into our estimate of the earth's age. The calculated mass of sodium contained in this rock-salt is 14,130 million million tonnes.

If now we can determine the rate at which the rivers supply sodium to the ocean, we can determine the age.[9] As the result of many thousands of river analyses, the total amount of sodium annually discharged to the ocean by all the rivers of the world is found to be probably not far from 175 million tonnes.[10] Dividing this into the mass of oceanic sodium we get the age as 80.7 millions of years. Certain corrections have to be applied to this figure which result in raising it to a little over 90 millions of years. By this method Sollas gets the age as between 80 and 150 millions of years. My own result[11] was between 80 and 90 millions of years; but I subsequently found that upon certain extreme assumptions a maximum age might be arrived at of 105 millions of years.[12] Clarke regards the 80.7 millions of years as certainly a maximum in the light of certain calculations by Becker.[13]

The order of magnitude of these results cannot be shaken unless on the assumption that there is something entirely misleading in the existing rate of solvent denudation. On the strength of the results of another and entirely different method of approaching the question of the earth's age (which shall be presently referred to), it has been contended that it is too low. It is even asserted that it is from nine to fourteen times too low. We have then to consider whether such an enormous error can enter into the method. The measurements involved cannot be seriously impugned. Corrections for possible errors applied to the quantities entering into this method have been considered by various writers. My own original corrections have been generally confirmed. I think the only point left open for discussion is the principle of uniformitarianism involved in this method and in the methods previously discussed.

In order to appreciate the force of the evidence for uniformity in the geological history of the earth, it is, of course, necessary to possess an acquaintance with that history. Some of the most eminent geologists, among whom Lyle and Geikie[14] may be mentioned, have upheld the doctrine of uniformity. It must here suffice to dwell upon a few points having special reference to the matter under discussion.

The mere extent of the land surface does not, within limits, affect the question of the rate of denudation. This arises from the fact that the rain supply is quite insufficient to denude the whole existing land surface. About 30 per cent of it does not, in fact, drain to the ocean. If the continents become invaded by a great transgression of the ocean, this "rainless" area diminishes: and the denuded area advances inward without diminution. If the ocean recedes from the present strand lines, the "rainless" area advances outward, but, the rain supply being sensibly constant, no change in the river supply of salts is to be expected.

Age-long submergence of the entire land, or of any very large proportion of what now exists, is negatived by the continuous sequence of vast areas of sediment in every geological age from the earliest times. Now sediment-receiving areas always are but a small fraction of those exposed areas whence the sediments are supplied.[15] Hence in the continuous records of the sediments we have assurance of the continuous exposure of the continents above the ocean surface. The doctrine of the permanency of the continents has in its main features been accepted by the most eminent authorities. As to the actual amount of land which was exposed during past times to denudative effects, no data exist to show it was very different from what is now exposed. It has been estimated that the average area of the North American continent over geologic time was about eight-tenths of its existing area.[16] Restorations of other continents, so far as they have been attempted, would not suggest any more serious divergency one way or the other.

That climate in the oceans and upon the land was throughout much as it is now, the continuous chain of teeming life and the sensitive temperature limits of protoplasmic existence are sufficient evidence.[17] The influence at once of climate and of elevation of the land may be appraised at their true value by the ascertained facts of solvent denudation, as the following table shows:

	Tonnes removed in solution per square mile per annum.	Mean elevation. Meters.
North America	79	700
South America	50	650
Europe	100	300
Asia	84	950
Africa	44	650

In this table the estimated number of tonnes of matter in solution which for every square mile of area the rivers convey to the ocean in one year is given in the first column. These results are compiled by Clarke from a very large number of analyses of river waters. The second column of the table gives the mean heights as meters above sea level of the several continents, in cited by Arrhenius.[18]

Of all the denudation results given in the table, those relating to North America and to Europe are far the most reliable. These show that Europe with a mean altitude of less than half that of North America sheds to the ocean 25 per cent more salts. Hence if it is true, as has been stated, that we now live in a period of exceptionally high continental elevation, we must infer that the average supply of salts to the ocean by the rivers of the world is less than over the long past, and that, therefore, our estimate of the age of the earth as already given is excessive.

There is, however, one condition which will operate to unduly diminish our estimate of geologic time, and it is a condition which may possibly obtain at the present time. If the land is, on the whole, now sinking relatively to the ocean level, the denudation area tends, as we have seen, to move inwards. It will thus encroach upon regions which have not for long periods drained to the ocean. On such areas there is an accumulation of soluble salts which the deficient rivers have not been able to carry to the ocean. Thus the salt content of certain of the rivers draining to the ocean will be influenced not only by present denudative effects, but also by the stored results of past effects. Certain rivers appear to reveal this unduly increased salt supply: those which flow through comparatively arid areas. However, th flow-off of such tributaries is relatively small and the final effects on the great rivers apparently unimportant —a result which might have been anticipated when the extremely slow rate of the land movements is taken into account.

The difficulty of effecting any reconciliation of the methods already described and that now to be given increases the interest both of the former and the latter.

THE AGE BY RADIOACTIVE TRANSFORMATIONS.

Rutherford suggested in 1905 that as helium was continually being evolved at a uniform rate by radioactive substances (in the form of the alpha rays) a determination of the age of minerals containing the radioactive elements might be made by measurements of the amount of the stored helium and of the radioactive elements giving rise to it. The parent radioactive substance is —according to present knowledge—uranium or thorium. An estimate of the amounts of these elements present enables the rate of production of the helium to be calculated. Rutherford shortly afterwards found by this method an age of 240 millions of years for a radioactive mineral of presumably remote age. Strutt, who carried his measurements to a wonderful degree of refinement, found the following ages for mineral substances originating in different geological ages:

Oligocene	8.4	millions	of years.
Eocene	31	"	"
Lower Carboniferous	150	"	"
Archæan	710	"	"

Another product of radioactive origin is lead. The suggestion that this substance might be made available to determine the age of the earth also originated with Rutherford. We are at least assured that this element cannot escape by gaseous diffusion from the minerals. Boltwood's results on the amounts of lead contained in minerals of various ages, taken in conjunction with the amount of uranium or parent substance present, afforded ages rising to 1,640 millions of years for Archæan and 1,200 millions for Algonkian time. Becker, applying the same method, obtained results rising to quite incredible periods: from 1,671 to 11,470 millions of years. Becker maintained that original lead rendered the determinations indefinite. The more recent results of Mr. A. Holmes support the conclusion that "original" lead may be present and may completely falsify results derived from minerals of low radioactivity in which the derived lead would be small in amount. By rejecting such results as appeared to be of this character, he arrives at 370 millions of years as the age of the Devonian.

I must now describe a very recent method of estimating the age of the earth. There are, in certain rock-forming minerals, color-changes set up by radioactive effects. The minute and curious marks so produced are known as haloes; for they surround, in ring-like forms, minute particles of included substances which contain radioactive elements. The particle in the center of the halo contains uranium or thorium, and, necessarily, along with the parent substance, the various elements derived from it. In the process of transformation giving rise to these several derived substances, atoms of helium, projected with great velocity into the surrounding mineral—the alpha rays—occasion the color changes referred to. These changes are limited to the distance to which the alpha rays penetrate; hence the halo is a spherical volume surrounding the central substance.[19]

The time required to form a halo can be found if on the one hand we could ascertain the number of alpha rays ejected in, say, one year from the nucleus of the halo, and, on the other, if we determine by experiment just how many alpha rays were required to produce the same amount of color alteration as we perceive to extend around the nucleus.

The latter estimate is fairly easily and surely made. But to know the number of rays leaving the central particle in unit time we require to know the quantity of radioactive material in the nucleus. This cannot be directly determined. We can only, from known results obtained with larger specimens of just such a mineral substance as composes the nucleus, guess at the amount of uranium, or it may be thorium, which may be present.

This method has been applied to the uranium haloes of the mica of County Carlow.[20] Results for the age of the halo of from 20 to 400 millions of years have been obtained. This mica was probably formed in the granite of Leinster in late Silurian or in Devonian times.

The higher results are probably the least in error, upon the data involved; for the assumption made as to the amount of uranium in the nuclei of the haloes was such as to render the higher results the more reliable.

This method is, of course, a radioactive method, and similar to the method by helium storage, save that it is free of the risk of error by escape of the helium, the effects of which are, as it were, registered at the moment of its production, so that its subsequent escape is of no moment.

REVIEW OF THE RESULTS.

By methods based on the approximate uniformity of denudative effects in the past, a period of the order of 100 millions of years has been obtained as the duration of our geological age; and consistently whether we accept for measurement the sediments or the dissolved sodium. We can give reasons why these measurements might afford too great an age, but we can find absolutely no good reason why they should give one much too low.

By the storage of radioactive products ages have been found which, while they vary widely among themselves, yet claim to possess accuracy in their superior limits, and exceed those derived from denudation from nine to fourteen times.

In this difficulty let us consider the claims of the radioactive method in any of its forms. In order to be trustworthy it must be true: (1) that the rate of transformation now shown by the parent substance has obtained throughout the entire past, and (2) that there were no other radioactive substances, either now or formerly existing, except uranium, which gave rise to lead. As regards methods based on the production of helium, what we have to say will largely apply to it also. If some unknown source of these elements exists we, of course, on our assumption over-estimate the age.

As regards the first point: In ascribing a constant rate of change to the parent substance—which Becker (*loc. cit.*) describes as "a simple though tremendous extrapolation"—we reason upon analogy with the constant rate of decay observed in the derived radioactive bodies. If uranium and thorium are really primary elements,

[9] *Trans. R.D.S.* 1899. A paper by Edmund Halley, the astronomer, in the *Philosophical Transactions of the Royal Society* for 1715, contains a suggestion for finding the age of the world on somewhat similar lines. He proposes to make observations on the saltness of the seas and ocean at intervals of one or more centuries, and from the increment of saltness arrive at their age. The measurements, as a matter of fact, are impracticable. The salinity would only gain (if all remained in solution) one millionth part in 100 years; and, of course, the continuous rejection of salts by the ocean would invalidate the method. The last objection also invalidates the calculation by T. Mellard Reade (*Proc. Liverpool Geol. Soc.* 1876) of a minor limit to the age by the calcium sulphate in the ocean. Both papers were quite unknown to me when working out my method. Halley's paper was, I think, only brought to light in 1908.

[10] J. W. Clarke, *A Preliminary Study of Chemical Denudation* (Smithsonian Miscellaneous Collections, 1910).

[11] *Loc. cit.*

[12] "The Circulation of Salt and Geological Time" (*Geol. Mag.* 1901, p. 350).

[13] Becker (*loc. cit.*), assuming that the exposed igneous and archæan rocks alone are responsible for the supply of sodium to the ocean, arrives at 74 millions of years as the geological age. This matter was discussed by me formerly (*Trans. R.D.S.* 1899, pp. 54 *et seq.*). The assumption made is, I believe, quite inadmissible. It is not supported by river analyses, or by the chemical character of residual soils from sedimentary rocks. There may be some convergence in the rate of solvent denudation, but—as I think on the evidence—in our time unimportant.

[14] See especially Geikie's Address to Sect. C., Brit. Assoc. Rep. 1899.

[15] On the strength of the Mississippi measurements about 1 to 18 (Magee, *Am. Jour. of Sc.* 1892, p. 188).

[16] C. Schuchert, *Bull. Geol. Soc. Am.*, vol. xx. 1910.

[17] See also Poulton, Address to Sect. D., Brit. Assoc. Rep. 1896.

[18] *Lehrbuch der Kosmischen Physik*, vol. I. p. 347.

[19] *Phil. Mag.*, March 1907 and February 1910; also *Bedrock*, January 1913.

[20] Joly and Rutherford, *Phil. Mag.*, April 1913.

however, the analogy relied on may be misleading; at least, it is obviously incomplete. It is incomplete in a particular which may be very important: the mode of origin of these parent bodies—whatever it may have been—is different to that of the secondary elements with which we compare them. A convergence in their rate of transformation is not impossible, or even improbable, so far as we know.

As regards the second point: It is assumed that uranium alone of the elements in radioactive minerals is ultimately transformed to lead by radioactive changes. We must consider this assumption.

Recent advances in the chemistry of the radioactive elements have brought out evidence that all three lines of radioactive descent known to us—i. e. those beginning with uranium, with thorium, and with actinium—alike converge to lead.[21] There are difficulties in the way of believing that all the lead-like atoms so produced ("isotopes" of lead, as Mr. Soddy proposes to call them) actually remain as stable lead in the minerals. For one thing there is sometimes, along with very large amounts of thorium, an almost entire absence of lead in thorianites and thorites. And in some urano-thorites the lead may be noticed to follow the uranium in approximate proportionality, notwithstanding the presence of large amounts of thorium.[22] This favors the assumption that all the lead present is derived from the uranium. The actinium is present in negligibly small amounts.

[21] See Soddy's *Chemistry of the Radioactive Elements* (Longmans, Green & Co.).

[22] It seems very difficult at present to suggest an end product for thorium, unless we assume that, by loss of electrons, thorium E, or thorium-lead, reverts to a substance chemically identical with thorium itself. Such a change—whether considered from the point of view of the periodic law or of the radioactive theory—would involve many interesting consequences. It is, of course, quite possible that the nature of the conditions attending the deposition of the uranium ores, many of which are comparatively recent, are responsible for the difficulties observed. The thorium and uranium ores are, again, specially prone to alteration.

On the other hand, there is evidence arising from the atomic weight of lead which seems to involve some other parent than uranium. Mr. Soddy, in the work referred to, points this out. The atomic weight of radium is well known, and uranium in its descent has to change to this element. The loss of mass between radium and uranium-derived lead can be accurately estimated by the number of alpha rays given off. From this we get the atomic weight of uranium-derived lead as closely 206. Now the best determinations of the atomic weight of normal lead assign to this element an atomic weight of closely 207. By a somewhat similar calculation it is deduced that thorium-derived lead would possess the atomic weight of 208. Thus normal lead might be an admixture of uranium- and thorium-derived lead. However, as we have seen, the view that thorium gives rise to stable lead is beset with some difficulties.

If we are going upon reliable facts and figures, we must, then, assume: (*a*) That some other element than uranium, and genetically connected with it (probably as parent substance), gives rise, or formerly gave rise, to lead of heavier atomic weight than normal lead. It may be observed respecting this theory that there is some support for the view that a parent substance both to uranium and thorium has existed or possibly exists. The evidence is found in the proportionality frequently observed between the amounts of thorium and uranium in the primary rocks.[23] Or: (*b*) We may meet the difficulties in a simpler way, which may be stated as follows: If we assume that all lead is derived from uranium, and at the same time recognize that lead is not perfectly homogeneous in atomic weight, we must, of necessity, ascribe to uranium a similar want of homogeneity; heavy atoms of uranium giving rise to heavy atoms of lead and light atoms of uranium generating light atoms of lead. This assumption seems to be involved in the figures upon which we are going. Still relying on these figures, we find, however, that existing uranium cannot give rise to lead of normal atomic weight. We can only conclude that the heavier atoms of uranium have decayed more rapidly than the lighter ones. In this connection it is of interest to note the complexity of uranium as recently established by Geiger, although in this case it is assumed that the shorter-lived isotope is genetically connected with the longer-lived and largely preponderating constituent. There does not seem to be any direct proof of this as yet, however.

[23] Compare results for the thorium content of such rocks (appearing in a paper by the author *Cong. Int. de Radiologie et d' Electricité*, vol. I. 1910, p. 373) and those for the radium content, as collected in *Phil. Mag.*, October 1912, p. 697.

From these considerations it would seem that unless the atomic weight of lead in uraninites, etc., is subnormal, the former complexity and more accelerated decay of uranium are involved in the data respecting the atomic weights of radium and lead and the radioactive events which occur in the transmutation of the one into the other. As an alternative view, we may assume, as in our first hypothesis, that some elementally different but genetically connected substance, decaying along branching lines of descent at a rate sufficient to practically remove the whole of it during geological time, formerly existed. Whichever hypothesis we adopt we are confronted by probabilities which invalidate time-measurements based on the lead and helium ratio in minerals We have, in short, grave reason to question the measure of uniformitarianism postulated in finding the age by any of the known at present radioactive methods.

That we have much to learn respecting our assumptions, whether we pursue the geological or the radioactive methods of approaching the age of our era, is, indeed, probable. Whatever the issue it is certain that the reconciling facts will leave us with much more light than we at present possess either as respects the earth's history or the history of the radioactive elements.

Sea-Salt and Geologic Time*

A Discussion of Prof. Joly's Method of Determining the Age of the World

By H. S. Shelton, B.Sc.

THE present short article is a reversion to an aspect of the subject of geologic time which I had thought to be settled, and to require no further research or controversy. In my review of Mr. Holmes's book[1] I commented strongly on his ignorance of current literature. I now find that the same imperfect acquaintance with recent discussion and research is shared by the writer who is responsible for putting forward the amount of sodium in the sea as an index of geologic time. I assume, of course, that ignorance is the explanation, for I take it that no man of science of recognized position, when the errors of his research had been pointed out, would deliberately ignore the fact, and proceed as if his work was a valid contribution to the advancement of science. My excuse, therefore, for writing an article containing nothing material which I have not previously published is the following passage, for which Sir Ernest Rutherford and Prof. Joly are jointly responsible:

"But it is certain that, if the higher values so found are reliable, the discrepancy with estimates of the age of the ocean, based on the now well-ascertained facts of solent denudation, raises difficulties which at present seem inexplicable."[2]

The values of geologic time referred to, based on radioactive methods, especially the age of pleochroic haloes, I propose to criticize on a future occasion. There are good grounds, which cannot be stated here, for thinking that all attempts to assess exact times for particular geologic epochs by calculation either of the lead ratios of uranium minerals or otherwise are premature, and are based on an imperfect realization of the complexity of the subject. The object of the present article, however, is to repeat[3] the arguments which show that the alternative method based on the salt-content of the ocean is of no value whatever. Not only is the discrepancy not inexplicable, there is no discrepancy to explain. So much did I take this for granted that, in my last article on the subject,[4] I did not think it necessary to consider the sea-salt method. I therefore take this opportunity to repeat the arguments, and to remedy what is apparently a deficiency.

Prof. Joly's original paper[5] was based on the supposed facts (1) that, as roughly estimated by Sir John Murray, of the solid matter dissolved in river water which reaches the sea 3.47 per cent is sodium; (2) that nearly all this hypothetical sodium is obtained by erosion of the rocks; (3) that when this hypothetical sodium reaches the sea, none of it returns to the rocks. On this supposition, dividing the amount of sodium in the sea by the amount which reaches it each year, an estimate of geologic time could be made. The objection is, briefly, that the three supposed facts are merely supposed facts. No single one of them is reliable.

For convenience we will take the second point first. Of the sodium which actually reaches the sea, a considerable proportion is associated with chlorine. None of the sodium chloride in the rivers can be attributed to erosion. This is so for two reasons. In the first place, it is well known that the proportion of chlorine in the rocks, igneous or sedimentary, is infinitesimal. In the second place, the sources of the chlorine have been thoroughly well determined. In the main, they are two, cyclic salt, carried by the wind from the sea, and salt due to human contamination. It has been found possible, particularly in New York State, to eliminate the cyclic salt, the amount of which is a function of the distance from the coast, and to show that the residual chlorine in river water is a direct function of density of population. Unless you take the sewage from town and country districts directly out to sea, the salt in it inevitably reaches the rivers. If you obtain an abnormally high chlorine ratio when the sewage is supposed to be carried out to sea, the inference is leakage. The source which would naturally occur to any one, brine-springs, has been shown to be negligible. Even in New York State, where brine-springs are plentiful, there is no appreciable effect on the salt content of the rivers.[6] The only known means by which fresh chlorine reaches the sea is volcanic action, and it is a point open to dispute how much of the volcanic chlorine is not ultimately derived from the sea. It follows, therefore, that, of the sodium which actually reaches the sea, only that not associated with the chlorine can be counted.

This much Prof. Joly and those who agree with his earlier estimate have been willing to admit. But Prof. Joly maintains that, if the chlorine equivalent of the sodium be substracted, there is still sufficient sodium to necessitate an estimate of geologic time less than 150 millions of years. His reason is merely Sir John Murray's rough tabulation of then current analyses and some more recent results. It does seem strange, however, that Prof. Joly never troubled to inquire whether there were any water analyses sufficiently accurate for this purpose. It is highly probable that Prof. Joly's original paper would never have been written if he had understood why water analyses are undertaken, and the manner in which they are actually performed. Had he been a water analyst, or even a chemist, the first thing that would have occurred to him would have been that these sodium determinations were decidedly hypothetical. Several chemists have expressed doubts as to the validity, but such discussions Prof. Joly has either ignored or failed to understand.[7] It may, therefore, surprise Prof. Joly to be informed that it is doubtful whether the sodium content of any single river water has ever been accurately determined. If any such cases have occurred, they are very few. Let us imagine that there is, in a given sample of river water, two parts of sodium per million. Such a proportion would be quite ordinary according to the usual tables. It would be a very interesting problem to try to separate this out and weigh it. To obtain a good weighable quantity (say 0.05 gram of sodium giving about 0.15 gram of sodium sulphate[8]) would require 25 liters of water, the greater part of a carboy, and the difficulties in the way of isolating it are such as any chemist can understand.

As a matter of fact, the accurate determination of the sodium is a form of amusement in which the ordinary water analysts do not indulge. Sometimes the alkalis sodium and potassium are determined together by difference, that is, not determined at all. In a paper[9] that has been sent to me recently the analyst describes his methods. In this case, everything possible is got rid of by the usual methods of precipitation, and the remainder is evaporated and weighed as "Sodium and Potassium Chlorides." The amount dealt with is only that from 250 cubic centimeters of filtered water, and would, of course, be infinitesimal, and the fact that it amounts to not more than 2 or 3 per cent of the total dissolved solid is a good indication of the general ac-

* Reprinted from *Science Progress*.

[1] *Science Progress*, July, 1913.

[2] *Philosophical Magazine*, May 1913, p. 657.

[3] The previous statements are: *Journal of Geology*, February-March 1910; *Contemporary Review*, February 1911.

[4] *Science Progress*, October 1913.

[5] *Trans. Royal Society, Dublin*, vol. 7, pp. 20*f*. Sir John Murray's paper *Scottish Geographical Magazine*, 1887. The results are best tabulated for the purposes of this discussion in the "Data of Geochemistry," U.S.A. Geological Survey Bulletin No. 330, p. 88.

[6] For further information on these points see Jackson's "Normal Distribution of Chlorine," U.S.A. Geological Survey, Water Supply Paper No. 144.

[7] See particularly discussion with Mr. Acroyd, *Chemical News*, 1901, and F. W. Clarke, *Data of Geochemistry*, p. 110.

[8] In ordinary accurate analysis sodium is usually weighed as sulphate. In water analysis, however, the quantity is so small that conversions to sulphate is not worth while. The residue is reckoned as chloride, though it need not necessarily be so.

[9] "The Quality of the Surface Waters of Illinois," U.S.A. Geological Survey, Water Supply Paper No. 239, p. 16. The method is the one usually recommended in the text-books. See Wanklyn, 11th edition, p. 122.

curacy of the analysis. The residue includes, of course, everything that is not caught by the filter throughout the whole operation. It should be mentioned, also, that the samples usually stand for days in glass bottles. In such cases of water analysis when the sodium and the potassium are separated, the separation is, needless to say, a very approximate operation.[10]

It is no reflection on the accuracy of river water analysts to say that the results are of no value whatever for Prof. Joly's purpose. No one, except Prof. Joly and a few geologists, wants to know the proportion of sodium in river water. It is at the same time the constituent least important for the purpose of the water analyst and the constituent most difficult to determine. The assumption on which Prof. Joly proceeds, that 3.47 per cent of the dissolved matter in river water is sodium, is absolutely unproven. For all the analyses prove, it might be less than half that amount. Indeed the principal evidence that there is an excess of sodium over and above its equivalent of chlorine is indirect rather than direct. The results of rock analyses are more reliable and it seems to be established that the sodium content of igneous rocks is greater than that of the aqueous. As a matter of fact it has been pointed out by Prof. Dubois that, when there is any reason to ascribe special accuracy to river-water analysis, the excess of sodium diminishes and tends to vanish. Prof. Dubois[11] collected a number of good analyses, tabulated them, and inferred from them, according to Prof. Joly's method, a geologic time of 400 million years. The inference he made, as he was a believer in Lord Kelvin's methods, was that the original sea was salt. The true inference is that the method is of no value. Within the limits of experimental error you can deduce any value you please.

Though the previous discussion renders it unnecessary, it is as well to mention one other point. The assumption that no sodium returns from the sea to the rocks is unwarranted. Indeed one instance to the contrary can be mentioned. It is a recognized fact that much of the salt in the salt lakes, and inferentially in salt beds, is windborne and has its origin in the sea. But what would occur when strata containing salt beds are subject to metamorphosis or are absorbed by the magna? Is it not obvious that the sodium would be added to the content of the rocks and that the chlorine would be expelled as some volatile compound? Indeed, is it not probable that some portion of volcanic chlorine has this origin? Again, with regard to the ordinary processes of the formation of sedimentary rock, we do not know enough to say that no dissolved sodium is reabsorbed.

This speculation, however, is a side issue, and is not necessary to the argument. Were the analyses of sufficient accuracy, were the method in general valid, such matters would require careful consideration. At present, without taking such remote speculations into account, we can still say that the sea-salt method is absolutely worthless. It is based on a misapprehension of the data on which it rests. It is an instance of the care that is required when results are transferred from one branch of science to another. With regard to geologic time, the value of radioactive methods is still to be determined. The value of the sea-salt method, like the still more famous ones of Kelvin and Tait, is nil.

The Optical Anisotropy of Liquid Crystals*

By B. O. Lehman

THE underlying purpose of all my work has been the proof of the untenability of the "Theory of Identity" of the molecule in all forms of a given substance, and the discovery of liquid crystals has furnished the direct proof sought.

I. The untenability of the "Theory of Identity":

(*a*) Transformation temperatures. Molten ammonium nitrate crystallizes at 161 degrees in very soft, regular crystals; at 125.6 degrees these again crystallize into harder tetragonal forms, and so at 82.80 degrees, 32.4 degrees, and —16 degrees firmer and firmer forms appear. Contrary to the Theory of Identity, I found, on reheating, that the melting points were identical with, and not higher, than these solidification points, from which I conclude that polymorphous transformation is a chemical process entailing alteration of the molecule; and from this follows the second conclusion that melting and vaporization change the molecule, otherwise two different modifications would furnish two different vapors and liquids.

(*b*) The plasticity of crystals. According to the Theory of Identity, there could be no flowing, or true plasticity of crystals; nothing but a "translation" of crystal fragments. My work with ammonium nitrate proved that there do exist plastic crystals, i. e., crystals whose fragments are no larger than single molecules. In the case of silver iodide, above 146 degrees no limit of elasticity could be demonstrated, and the "snapping" of the molecules into definite orderly arrangement was very doubtful.

(*c*) The solubility of distorted crystals. If variation in solubility of polymorphous forms is due purely to molecular arrangement, as the Theory of Identity presupposes, then plastic distortion of crystals (i. e., a disturbance of the molecular arrangement) should alter the solubility. This is not found to be the case.

Although thoroughly convinced that the Theory of Identity was false, and that the soft regular crystals of ammonium nitrate and silver iodide were truly liquid, still I was not able to give actual proof that they possessed no limit of elasticity.

II. Reinitzer's isotropic liquid with oily streaks:

After prolonged research I recognized that Reinitzer's isotropic liquid in which crystals and oily streaks are present is different from the isotropic molten mass, and that in all probability it is an entirely irregularly arranged aggregate of the same molecules of which the crystals and oil streaks consist. This conclusion is another contradiction of the Theory of Identity.

III. The first liquid crystals:

Absolute proof of the existence of liquid crystals I first obtained with ammonium oleate hydrate. The polyhedric form of the tiny crystals can be explained only by a more or less disturbed molecular arrangement, and the phenomena of spontaneous homœotropy (the immediate automatic restoration of structure after distortion division or fusion of the crystal units) entirely excludes from the realm of possibility the existence of a "limit of elasticity." No further proof can be asked for the existence of liquid crystals.

IV. Classification of crystalline liquids:

From my standpoint the anisotropy of the molecules, and not their order of arrangement, is the prime factor in determining the classification of a crystalline substance, hence I classify liquid and solid crystals exactly alike, according to their optical properties: (1) Monosymmetrical, (2) asymmetrical, (3) regular, (4) tetragonal and hexagonal, (5) rhombic, etc.

The Sense of Smell in Insects

THE Smithsonian Institution has recently issued a paper, by Dr. N. E. McIndoo, dealing with the olfactory sense of insects, which consists of a general review of this unusually confused subject, presenting the views of different authors, discussing the seat of the olfactory organs, summarizing the author's experiments, and citing a large number of scientific treatises on the subject, which comprises the first classification of such literature.

From the views of very early writers, including Aristotle, Virgil, Pliny, and others, it is evident that the belief in a sense of smell in insects has long been known and believed generally; also that some insects are able to distinguish various odors. While it is seldom denied that insects can smell, no one has yet ascertained the relative sensitiveness for any particular species, nor is the seat of the organs definitely located for all species.

The writings discussed are classified according to their viewpoints, as to the seat of the olfactory organs, which seems to be the main point of disagreement among them. One theory which has long since been abandoned was that these organs were located in the spiracles or nostrils of the insects as in the case with the higher animals, but it was advocated by assumption rather than experiment, as no one has found any nerves or organs which suggest an olfactory function either in the spiracles or in the trachea, the windpipe.

One author holds that these organs are located in the throats of the various insects; one in the mouth cavity; several in the feelers attached to the mouth; many in the antennæ; and so on, until nearly every available portion of the insect's anatomy has been suggested by one or another student. Dr. McIndoo, however, has proved by experiments that many of these theories are wrong, by covering up, removing or otherwise eliminating various organs, and testing the smell of bees, ants, and hornets thus treated, nearly all of which respond as readily and as quickly to the fraction of a second as normal bees, ants, and hornets under similar conditions.

About one half of his experiments were conducted to disprove the somewhat general belief that the sense of smell of insects is located in the antennæ, the horns or feelers attached to the head, constituting the organs of touch. To this end the experimenter tested honeybees, ants, and hornets by removing one or both of their antennæ and noting the results when the insects were subjected to the odors from the essential oils of peppermint, thyme ,and wintergreen. Honey, pollen, pennyroyal, formic acid from ants, etc., were also used in testing the sense of smell.

After disproving the theories of all the other writers concerning the seat of the olfactory organs, the author began to search for organs similar to those which found a few years ago in spiders. These organs w soon found on the legs and wings of all the inse examined. Many experiments were performed whi proved conclusively to the author that these organs a the true apparatus for receiving odor stimuli in t insects tested.

It is certain that spiders can smell, yet they have antennæ nor any organs that may be compared to t antennal organs of insects. This is another argume against the antennæ being organs of smell. All insect either have antennal organs like those of the bees, o modifications of them, yet no two authors who hav studied them have agreed concerning their functio Such chaos can be replaced by facts, only when th behavior of the insects investigated is thoroughl studied and when experiments are performed in way other than on the antennæ alone. Then it will be rea ized that the antennæ can no longer be regarded as possible seat of the sense of smell in insects.

In conclusion, it seems that the organs called th olfactory pores by the author are the true olfactory ap paratus in bees, ants, and hornets, and possibly in al insects, and that the antennæ play no part in receivin odor stimuli.

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[10] The potassium determination would be the more accurate of the two, as the potassium is weighed as Pt. + 2KCl. A further percentage of inaccuracy would thus be thrown on the sodium.

[11] *Proceedings Amsterdam Academy*, 1904.

* Translated from *Physikalische Zeitschrift* for the SCIENTIFIC AMERICAN SUPPLEMENT.